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TABLE OF CONTENTS

Summer School for Engineering Teachers, Sessions of 1931. H. P. Hammond 263
Personal Relations of Teachers
With Fellow Members of the Faculty. J. W. Barker 265
With Students. Charles L. Kinsloe 269
With the Community...C. H. Mitchell 274
With Industry. R. E. Doherty 277
The Responsibility of the Engineering Teacher. William E. Wickenden .. 280
Getting Students to Stay Taught. Francis T. Spaulding 287
The Division of Co-operative Engineering Education 304
Report of Conference on Co-operative Engineering Education:
Railroad Work as a Valuable Practical Experience for Co-operative Students. J. E. McDaniel 305
The Co-operative Plan Applied to Aeronautical Engineering. F. K. Teichmann and C. W. Lytle 310
Engineering Courses in School of Business Curricula. George Filipetti 318
An Experiment in Industrial Education. G. B. Thomas 324
Co-operative Education from the Industrial Viewpoint. E. B. Roberts 332
Discussion 336
T-Square Page 344
The Place of Solid Geometry in Mathematics Curricula and Some Methods of Presenting the Subject. Louis O'Shaughnessy 345
New Members 351
Discussion: Can the Engineering Student be Taught to Manage Men? ... 352
Photographs of Prominent Engineers 352

CONTENTS

College Notes:
George Washington University 353
Harvard Engineering School 353
Massachusetts Institute of Technology 354
Swarthmore College 354
Sections and Branches:
Colorado School of Mines 355
Kansas-Nebraska 355
Minnesota 358
Necrology: Brother Azarias Michael 359
Book Reviews 359

353
353
354
354
355
355
358
359
359

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HAMMOND, H. P., Director of S. P. E. E. Summer School, 99 Livingston Street, Brooklyn, N. Y.

SUMMER SCHOOL FOR ENGINEERING TEACHERS SESSIONS OF 1931

By H. P. HAMMOND, *Director of Summer Schools*

Excellent progress is being made in preparation for the two sessions of the Summer School to be held in 1931 which were announced in the September, 1930, number of the Journal.

The session on chemical engineering will be held at the University of Michigan beginning June 24. The party will be in residence at Ann Arbor from June 24 to July 8, inclusive, after which a trip of inspection to chemical industries, from July 9 to 14, inclusive, will be arranged for the members of the session on a voluntary basis.

The program of the chemical engineering session will be so arranged as to be of interest to teachers of allied branches, such as gas engineering and ceramics, in addition to teachers of chemical engineering. The program is divided into the following five major parts:

1. Principles of Teaching,
2. Teaching Chemical Engineering and Allied Subjects,
3. Applications of Principles of Chemical Engineering,
4. Miscellaneous, including History,
5. Recreation and Inspections.

The major portion of the program will be devoted to the second of the above divisions, and will include the aims and purposes of chemical engineering education, organization and content of curriculum, content and methods of teaching the major course in unit processes of chemical engineering, and the methods of organizing and conducting chemical engineering laboratory instruction. Divisions 1, 2 and 4 of the program will be in charge chiefly of teachers of chemical engineering and division 3 chiefly in charge of practicing chemical engineers.

The staff, as in previous sessions of the Summer School, will be recruited from among the foremost teachers, scientists and engineers of the country. It will be headed by Professor Alfred H. White, of the Department of Chemical Engineering, University of Michigan, Local Director, and Professor W. L. McCabe, Secretary.

Facilities at Ann Arbor are very satisfactory for the Summer School group. Jordan Hall, a new dormitory unit, will be available, the cost of room and meals being approximately $17 per week. Sessions of the School will be held in the east engineering building of the University.

Final details of the program are being arranged in coöperation with a committee representing the American Institute of Chemical Engineers. This organization is sponsoring the session.

The mathematics session of the Summer School will be held at the University of Minnesota from August 24 to September 5, 1931, inclusive. Dean O. M. Leland, of the College of Engineering and Architecture, is the Local Director of the session and Professor C. A. Herrick will serve as Secretary.

The program of the mathematics session includes the discussion of principles of teaching in general, the principles and methods of teaching college courses in mathematics, the presentation of certain selected phases of advanced mathematics, the applications of mathematics in science and industry, coördination of mathematics with secondary school instruction and with the professional subjects of engineering curricula, the history of mathematics and other topics.

The program of the session is being arranged in coöperation with an advisory committee representing the American Mathematical Society and the Mathematical Association of America, and, through Chairman E. R. Hedrick, with the S. P. E. E. committee on mathematics.

Further information concerning the mathematics session will be published in an early number of the Journal.

Applications to attend either session should be mailed to the Director of Summer Schools, S.P.E.E., 99 Livingston St., Brooklyn, N. Y. Such applications may take the form merely of a letter noting the name of the institution, and the academic title and teaching experience of the applicant.

PERSONAL RELATIONS OF TEACHERS *

WITH FELLOW MEMBERS OF THE FACULTY

By J. W. BARKER

Dean of Engineering, Columbia University

As General Rees has said, the relationship of one member of the faculty with all the other members of the faculty is one of the most important points in carrying out our concerted objective of developing these young men who come to us from the high schools into men who some day will become engineers. I think none of us fool ourselves into believing we are turning out engineers. Paul Lincoln said a good many years ago, that the objective of an engineering school was to turn out men who had been given such an impetus that some day they would become engineers.

In this inter-relationship between the various faculty members, there are a number of points I believe we should consider very carefully. In the first place, there is the natural point-to-point contact which arises mainly within our own departments. An educational institution is a democratic, and must be a democratic institution. That means there is no room for a single-handed autocracy. On the other hand, an institution which runs by the will of the majority alone very seldom will arrive at a concerted and definite objective. Therefore, in our work together we must delegate certain of our perogatives and certain of our work to various committees, and it is in the committee work of the faculty that I believe we most often fail.

Of course, I had a number of years' training in the army and I never can forget one of the questions which is on every army officer's annual efficiency report. It is the one question, I believe, which gives the greatest indication of the man's worth in carrying out a concerted objective. This question is asked yearly concerning each officer in the army. Superior authority having decided upon a particular objective, does he willingly and loyally cooperate to carry out that objective? I wish in many respects that same question were asked of each member of the faculty yearly. Properly constituted authority having decided upon a particular line of attack, does he willingly and loyally coöperate to carry out that line of attack?

In our committee work is the place where we determine in general the lines of attack. We must do so. Faculty meetings are too

* Presented at the 38th Annual Meeting, S. P. E. E., at Montreal, Canada, June 26–28, 1930.

large ever to lay out a concerted line of endeavor and say, "This is the direction along which we want our particular school or our particular college, or our particular university to progress." However, in that committee work I believe it is important that, until the time of the decision of the committee, there be the fullest and freest discussion. Some younger members of the faculty are appointed to these various committees, and properly so appointed, in order to bring to the committee the point of view of the younger chap, who is possibly of an age nearer that of the student, and therefore probably better reflects the student attitude, the student thought. These younger committee members hesitate very greatly to bring up before the committee their reflections upon the particular subject of discussion. Yet if a committee has been properly appointed, the reflections of each individual member in laying out the policy of the committee are very, very important. Often these younger members have for some reason failed to give their views and the committee work has suffered.

The older members of the staff have a great tendency to discuss rather casually any comments the younger members make, and yet it is just exactly those comments which bring us more closely in contact with the reaction we may reasonably expect to get from the student body. Therefore, my plea for committee work is for the fullest and freest discussion up until the time any question of policy is put to a vote. After that, my second plea is for practically a unanimous vote. A committee that leaves a meeting having decided upon a line of attack on a particular problem, divided against itself, with certain members after they have voted on the subject talking against it, is almost impotent.

Therefore, in the department or faculty committee work I want to leave two points of view as my own idea with you. First, the fullest and freest discussion, both pro and con, on every point that comes before the committee. Second, after the committee has taken its vote, that the committee go out of the room unanimous in favor of the particular line of attack which has been decided by majority vote.

Faculty meetings are very much the same way. Our committees report to the faculty. Again, unless the committee acts with power for the faculty, there should be the fullest and freest discussion of this committee's report. Then the faculty itself, after having acted upon it in its due judgment, should lay aside any personal opinion as to the right or wrong, good or bad of the particular point of view, and act unanimously in loyally coöperating to carry out the majority decision of the faculty. We have all experienced times in committee meetings and faculty meetings when this has not been the case. The committee has made a decision, they come

in, go to the faculty meeting, and nearly half of the members of the committee will argue in the faculty meeting against the report of their own committee. While that may sound as if I were arguing for the autocracy of the committee, I am not. I simply believe that no committee should report out a matter of major importance until it can have argued itself into the frame of mind where it is practically unanimous.

So much for the committee work and the faculty work.

Another of the things which I believe is of the greatest importance is our own social life, one with the other. I have seen more points of major importance to the university settled outside of the faculty room over the tea table, or in the smoking room, and settled satisfactorily, than I have ever seen settled in committee. Only too frequently you take a committee with very divergent opinions out of the committee room and feed them a little coffee or tea, and sit down and smoke, and you can bring them around until they are all unanimous in favor of a particular line of attack. By that I do not mean that there is no necessity for give and take. Necessarily there must be such, but the give and take is more easily expressed I think over a tea cup than it is in a formal faculty meeting or in a formal committee meeting. So that the next part of my plea is for the importance of maintaining our personal relationships on the friendliest of planes.

It seems to me there are three important effects which come from this increase in the social life of the faculty. First is the broadening effect. We have all heard a great deal of talk about it. The engineer has been accused of being narrow. Personally, I do not agree with that point of view for one moment, but it may be so. Certainly if it is so, the more contact we have with our arts friends outside of the classroom and outside of the committee room, and outside of formal faculty meetings, the more broadened we will be; and if the reverse of the case is so, that the engineer is the broader chap, then so much the better for the arts chap to come in contact with him outside of the faculty. Therefore, I make this plea for a broader social life from the point of view that it does exert a broadening effect upon each individual member of the faculty and their wives who come in contact with them, because the ladies exert a very potent effect in every faculty, as you well know.

There is a second point which this social life brings up. We all of us think our own particular subject is of the greatest importance. I wouldn't for one moment detract from that point of view. Yet with everyone of us thinking our own subject is of the greatest importance, certainly there ought to be some interesting informal discussions about the relative importance of things. The point I wish to bring up is if we stay tied down to our particular

subject we will tend to develop an ingrowing disposition, and there is no finer way I know of to eliminate an ingrowing disposition than to argue for the importance of our own particular subject with some other member of some other college or faculty of the university. So that the development of our social life will tend to prevent our ingrowing dispositions.

Furthermore it will tend to prevent our developing a superiority complex. That word has been very heavily overused in the last few years, but it is the only one of which I can think at the present moment that expresses what I have in mind. We are all dealing for at least nine months of the year with immature minds, growing minds. We stand up before them and we often must deliver the laws of the "Medes and Persians" to them in our discussions. We inevitably tend to develop this so-called superiority complex, and yet by this social life, this intercourse between the various staffs of the college, of the engineering college, and between the various colleges of the university, we can work ourselves out of that superiority complex to the point where we appreciate very fully that each other man has a very important point of view to which it will pay us well to listen and from which to take pointers.

Thirdly, on the social point, we have to consider the situation which is arising and has arisen in all of the various engineering colleges. Much has been said about the raiding of the college faculties by industry. Much has been said about the underpayment of the faculties, with which of course I will take no issue. But I believe that by building up this social life among ourselves we can make university life so very attractive to us all that it will take a very potent influence to make us withdraw from our pleasant social intercourse, one with the other, to leave and go into industry or into some other work, of whatever description it may be.

So that in summing up the importance of this social side of the point of view, I want to bring out again these three things: the broadening effect one upon the other, the overcoming of this superiority complex, and the fostering of the morale of our staff.

Now there are a number of methods available, and I am one of the greatest believers in the so-called faculty club. A place where the faculty can meet socially, to lay aside completely the cares of the classroom, the cares of the office, and have luncheon together, discuss these various points of view informally, where we can have special lectures by visiting prominent personalities, where we can have our evening affairs, where there can be a residence for the bachelor members of the staff—it seems to me that such a faculty club can be of the greatest influence in molding our staffs and our faculty into one unanimous whole, a family of friends that works and lives and acts together to develop and bring out the best in

these young men who are delivered to us, and to make our particular school of great influence in the country today in fostering proper engineering education.

WITH STUDENTS

By CHARLES L. KINSLOE

Head, Dept. of Electrical Engineering, Pennsylvania State College

Closer personal contacts between teachers and undergraduate students in engineering colleges; how these contacts may be secured; and the best use to make of these contacts when they may occur are problems which are receiving more thoughtful attention now than at any time in the recent history of technical education. Constantly there is an increase of evidence to strengthen the belief that in spite of the many defects and weaknesses of the purely technical training of the engineering graduate, his most serious deficiencies are not those due to inadequate preparation in the subject matter of his curriculum. Failure of the young engineer to make satisfactory progress during the years immediately following his graduation usually may not be attributed to insufficient mastery of those subjects which are generally considered to be the fundamentals of his formal education. The leading engineering colleges, by constantly raising academic standards, limiting enrollments, strengthening teaching personnels, and improving methods of instruction, have done much to eliminate from graduating classes those men whose limited capacities and technical abilities would seem to disqualify them for successful participation in one or more of the diverse activities in the field of engineering.

With the realization of the fact that many of the ablest of the young engineers do not quickly develop qualities necessary for industrial leadership came insistence that engineering curricula be "broadened," "liberalized," "humanized." Increased formal instruction in one or more non-technical fields has been urged as a means of socializing the engineer and doubtless a limited compliance with this demand has been beneficial.

Perhaps the time has come when engineering colleges as well as industry must take a much more comprehensive and far reaching view of the whole complex and tremendously important problem. Conceivably they both need to realize that notwithstanding serious difficulties, physical as well as economic, which at present bar the way, the problem must be faced and correctly solved for there is no escape from the fact that the industrial life and the national life of the future vitally depend upon the trained leadership which must be drawn in very large measure from our engineering colleges of today.

The satisfactory solution of the problem is not to be found in any recasting of the content matter of engineering curricula, in the improvement of formal lecture room or laboratory instruction, in the accumulation of more elaborate and more costly equipments, nor in more highly organized or specialized "training periods" conducted by industry, although all of these are highly important. Fundamentally and essentially the problem is one of human relations and human contacts. It is concerned with the family relationships, the preparatory school days, the years in college and with the subsequent introduction into industrial life.

This paper attempts to deal briefly with only those personal relationships which exist, or which should exist, between the engineering student and his teacher.

If it be assumed that the college has taken all steps possible to provide the ablest teaching staff available and has selected its students with the utmost care, what can be done to assure the greatest and most worthwhile benefits from the association of these two essential groups during the four years in college? Are the present class room and office contacts the only ones that are practicable or desirable? To what extent should the influence of the teacher affect the life of the student? How may a closer association of teacher and student be secured?

For intimate relations obviously the small college, located in the typical "college town" has a distinct advantage not enjoyed by most of the more important technical institutions with their customary large undergraduate enrollments frequently coupled with a location in a metropolitan area. Generally, teaching schedules in the technical schools are heavier than those in the Arts colleges. There is constant pressure to increase the amount of graduate instruction offered and there is a natural and wholly commendable urge to participate to a greater degree in research. Too frequently all this has resulted in delegating in growing measure to graduate students and teaching assistants instructional duties for which their meagre training and lack of professional experience have not as yet properly prepared them.

Interesting projects lately have been announced by some of the largest universities which, when completed, should greatly assist in lessening difficulties due to city location and to large enrollments. Among these are the proposed new housing plans of Harvard and Yale universities and the recent decision of the trustees of the University of Pennsylvania to remove certain undergraduate departments to an entirely new suburban location at Valley Forge.

It may be of interest briefly to describe a few methods successfully employed by the Department of Electrical Engineering of

The Pennsylvania State College to make possible and encourage closer personal relations between the older and more experienced members of its teaching staff and the students coming under their direction. The instructional organization of the department consists of fifteen men holding professorial rank or that of instructor and all are on a full time basis. Every member of the staff has had considerable teaching as well as industrial experience. Each year there are enrolled in the department from four hundred and twenty-five to four hundred and fifty undergraduate students and in addition, some instruction is given by the same staff to about two hundred non-electrical engineering students. An average senior class is composed of eighty to ninety men and a typical freshman class is made up of about one hundred and thirty-five students.

Following the practice of the school of engineering of which the department is a division, each enrolled student is assigned to a member of the teaching staff who acts as the student's "Adviser." The Adviser is responsible for all matters pertaining to the student's schedule; he recommends and executes any necessary faculty actions and, in short, has complete supervision of the student's academic life. But of much greater importance is the fact that the Adviser has the opportunity of knowing his students personally and intimately. He may inform himself as to their living conditions, student associations, outside activities, their health and attitude of mind. At the same time the student soon acquires a degree of familiarity and friendliness with the Adviser which he seldom feels for the teacher whom he meets only in the lecture room. The Advisers are changed at the beginning of each college year so that at the time of graduation these contacts have been established between each student and four members of the staff.

Further intimate relationships between teachers and students are secured by means of an orientation course given during the second semester of the freshman year and continued through the first semester of the sophomore year. For this course students are divided into sections of fifteen men each. They meet in a specially designed and equipped laboratory for one three-hour period each week with some one of the older staff members. They undertake the solution of simple engineering problems, the data for which are secured by the students from comprehensive equipments illustrating electrical applications in diverse engineering fields. Informal talks and conferences, not only with the instructor in charge, but with other staff members as well, afford an excellent opportunity to give to the student a better engineering perspective and, also, an opportunity to discuss, somewhat leisurely, many personal problems of vital concern to the student.

Laboratory instruction, because of the character of the work and the longer periods involved, offers possibilities for more intimate association. Consequently, in the general laboratory courses, classes are divided into sections of fifteen men each and these sections are subdivided into working groups of three men each. Each student in turn serves as leader of his group and, while so serving, is directly responsible to the instructor for planning and conducting the work undertaken. This plan not only increases the student's sense of responsibility but, during each three-hour period, a group of five students is constantly cooperating with and assisting the experienced teacher in charge. The special laboratories, such as those devoted to communications, transmission, traction, and illumination, because the numbers involved are much smaller, afford even more favorable opportunity for much less standardized procedure and in them practically individual instruction becomes possible.

For the past six years many members of the senior class, who have shown marked interest and ability in one or more lines, have been afforded an opportunity to devote about one-fifth of the time of the final year to special work directed by the ablest teachers on the department staff and credit toward a degree is given for all work so done. Usually three or four students work with the same teacher on problems of common interest. The method employed is a combination of seminars and personal conferences. Invariably the work is of high order and arouses great interest in the students. At present this opportunity can be offered to about half of the seniors and the results have been exceedingly satisfactory.

During the college year 1929–30 a most interesting and promising experiment in engineering education was conducted by the department of electrical engineering with the cooperation of four great electrical industries: The American Telephone and Telegraph Company (and associated companies), The General Electric Company, The Westinghouse Electric and Manufacturing Company, and The West Penn Power Company. This experiment was quite fully described in a report submitted by Mr. R. E. Doherty at the eleventh Industrial Conference held at The Pennsylvania State College in May, 1930, and which shortly will be published in the Proceedings of that conference.

Fifteen outstanding seniors in electrical engineering and in electrochemical engineering were selected for a course of seminars continuing through the entire first semester. The course dealt with the functional organization of industry and each of the four supporting corporations assumed responsibility for the work of one month. During three weeks of each monthly period the students met about a conference table with major executives, engineers,

scientists, and commercial men selected from the particular industry in charge and during the remaining week of each month additional meetings were held with a member of the department staff. Thus the idea of personal contact was extended to include the industrial leader who, for a brief period, became the student's teacher and counsellor. The benefits to the students were very real and the plan, in a somewhat modified form, is to be continued during the next college year.

All of these plans are but imperfect attempts to supplement the older and more generally accepted methods of engineering education with something a little less standardized than that which has heretofore prevailed. They are first steps in an effort to deviate somewhat from the practice of dealing with engineering students en masse toward a more individualized form of instruction. It will be noted, too, that every move in the direction of instruction planned for the individual inevitably means an increased opportunity for closer personal relations.

Constantly we are reminded by those at the very pinnacle of present-day industrial leadership of the vital need of a new type of leadership for the future. For the creation of most of the problems and complexities, both economic and social, the scientist and the engineer are held responsible. Willingly or otherwise they are to be called upon, in increasing numbers, to participate in the *solution* of these problems. Research, discovery, invention, and industrial development are not to stand still. To carry on all of these activities, more and more technical men will be required. But in addition, to this new and different leadership, industrial and political, engineering must make a liberal contribution and, in very large measure, this contribution must come from the engineering colleges.

All of this requires the best technical training it may be possible to give but it demands infinitely more. It means that to our engineering colleges must come in greater numbers a type of student now frequently attracted to other fields—the boy with the intellectual ability required by the rigor of the engineering curriculum and who is also possessed of a keen interest in his fellow man. It means that our engineering faculties must extend their own horizons to include this broader professional perspective. It means that some way must be found to span the distance between the engineering student and his teacher.

WITH THE COMMUNITY

By BRIG.-GENERAL C. H. MITCHELL

Dean, Faculty of Applied Science, University of Toronto

The relation of a teacher to his university environment and the surrounding community is to-day no small measure of his usefulness. In the old days a university professor led a species of monastic life; he was concerned only with an academic life and his chief aim was to instruct only those who cared to come and sit at his feet. To-day it is different. Those times have long passed and, with the radiation of knowledge and learning from a university centre which is the present-day tendency, the real teacher fulfills his greater mission when he carries his influence to successive zones far beyond the walls of his university. It might not be going too far afield to remind ourselves of the striking slogan of an historic revivalist who embarked on his religious movement by saying "The world is my parish."

Let us, in considering this phase of university life and work, go back to first principles. Let us go back to those principles which underlie the young man's desire to acquire a university education. Whether he does so from the ambition to secure an education for its own sake—or rather for his own sake, or whether it is simply to place himself in a favorable position to gain a livelihood, it matters little. The fact is that he acquires the education by the combination of efforts primarily put forward by himself but secondarily by his parents, perhaps, and certainly by the community which places a university at his disposal at which to pursue his ambition. The contribution of the community in this sense may be either by means of a state university or an institution endowed from private sources. However it may be, it is provided for the student by his fellow citizens and he takes advantage of it.

This being so, is it not reasonable that the conscientious student should realize that he owes something to the community which has made his education possible? Is it not reasonable that he should seek some means, at some time in his career, by which he can discharge this obligation in some form? I am one of those who believe that all university graduates owe it as a duty to the community or the state to return to it something in the form of service which he can offer from time to time as he progresses in his career.

If this principle applies to the university graduate himself, is it not reasonable and logical that it can apply also to those who teach the graduate, themselves graduates like him but of an earlier decade? It might be said that teachers—whether senior professors or junior instructors—are already discharging, or have already discharged, any such obligation they may owe to the state or com-

munity by offering themselves for the profession of teaching. To such critics there is nothing more to be said. Those who are in the profession know from their own consciousness the extent and value of their rewards and realize the pleasure they derive from their profession.

The idea which underlies this broad principle, in so far as it can apply to the university professor is, in my opinion, that when he chooses that career, he weds the university and lives with it. Its interests become his interests. He helps adorn his home, he improves and beautifies his surroundings, he helps his neighbours and he enters into the social life of his neighbourhood. All this is natural in our everyday life. Why not apply it to our university life?

And what do these neighbours of the University expect? What is reasonable for them to expect of the university professor who goes in and out among them? The community may not realize that it expects anything, it may not know what it wants in the way of service and help. But it does know that the professor is an educated man, he is a person who knows a great deal more about his own subject and taken as a whole, all the professors of a university—a summation of them collectively—know vastly more than any coördinated collection of the members of the community. If, then, the community thinks about it at all—and all communities think in some form or other—it is only reasonable that it will expect its university neighbours to be neighbourly, to be friendly, to be helpful and even generous.

True neighbourliness must be reciprocal. It is not sufficient that neighbours simply meet on the streets, or in the shops, or in the markets and "pass the time of day" with each other. It must be a friendly intercourse in order to be genuinely neighbourly. Good neighbours, however, do not need to live on each others door steps or be unduly intimate, nor need they run in and out of each other's houses without knocking.

If the members of the university household visit freely with those of the community household, there can be a genuine helpful coöperation. They can even lend each other many things as good neighbours do—spades, brooms, dusters, grass cutters, and even food—for thought. And it surely can work equally both ways.

If the members of the community household are not sometimes asked to come and visit at the university—the big house on the hill—how can they appreciate how the university household lives and occupies its time. Looking at its windows and doors from a distance and watching its occupants coming and going is not good enough. There is an altogether different sense of friendliness and neighbourliness when the community—down town—can say, "Oh

yes, we have often been up there, we like to go, they are so friendly and hospitable."

On the other side of the picture let us visualize the university professor visiting and mingling with the community household, down in the city, "below College Street." Surely he is welcome. The city community is glad to see him. He adds to their sociability, to their widened interest in life and to their store of knowledge. He helps them with their problems and their work. Whether it be at the Parliament or State Buildings, at the City Hall, at the Chamber of Commerce, or in a Club corner; whether at the Stock Exchange, the Banks, the Art Gallery or the Museums, in the Music Hall, or in the lecture hall of the large hotel, or whether it is in the Church, the Hospital or the Neighbourhood Settlement, it is all the same. The university professor can be a very helpful neighbour and he who has done it knows how much it widens his own horizon and his university usefulness.

The ever widening usefulness and influence of the university is a sign of the changing times. The immediate university circle as it was several decades ago, is not enough, is not wide enough. Surrounding all universities there are organizations, not a part of the university proper but a definite part of university life and influence. In these there is much opportunity to exert effort and employ talent which a university gathers about it. Some members are more adapted to one and some to another form of activity but all can be useful in these contacts in the zone which immediately surrounds the university.

There are outer zones, wider and more far reaching. Some are concentric, some perhaps eccentric. Some are merely in contact and some are quite detached. All circles or zones, however, in whatever form they arrange themselves, show the character and breadth of the university influence, ever changing, widening or reforming though they be. The pattern may prove to be the distinctive design by which the university is known and has gained its fame.

Let us, in imagination, draw a diagram—it may look like the solar system and why should it not be similar? The university can shed its light and warmth to a wide expanse in our modern civilization.

We can draw the diagram in circles, in ovals, in ellipses, even in parabolas and hyperbolas, so long as there is some centre, some focus or some origin which is the university itself. We may even make our diagram in the colours of the spectrum, each denoting some characteristic which a member of the university can bring to some useful field or contribute to the pattern which is the spread-

ing decoration of the university in the community or in the country in which it is set.

If, then, the members of the university staff would enter into the fullness of this widespread vector diagram with its resultants, they will assuredly get their own rewards in the service which they can offer "Pro utilitate hominum." They will gain golden opinions from their fellow citizens, for a high encomium is paid to a university professor when it can be said of him "Below College Street he is a real citizen."

WITH INDUSTRY

By R. E. DOHERTY

Consulting Engineer, General Electric Company

The phase of this general subject which I have been asked to discuss is the teacher's relations with industry. It is generally acknowledged that some form of contact between the engineering teacher and industry is extremely desirable, if not essential, to effective educational work in engineering. The advantages are numerous. In the first place he is thrown in personal contact with practicing engineers who are doing the kind of work which many of his students will one day be doing. Knowing such engineers and their professional activities, he is better able to bring their point of view to the class room, and more appropriately to adjust his own. Secondly, he is able to pick up during such association in industry, engineering knowledge which will be helpful in his educational work. The extent of this, of course, depends somewhat upon the character of the work he does in industry. Another very important advantage, even if it is of a more or less intangible character, is that he becomes acquainted with the general atmosphere in the industry. He is thus in better position to answer students' questions in this connection. Although there are other values in such contacts, the foregoing are, in my opinion, by far the most important.

These contacts have a number of different forms. One important plan is the S. P. E. E. Summer School for engineering teachers which has been held during the past few summers in the immediate neighborhood of an industrial center, thus making it possible for the enrolled teachers to establish contact with industry during the session. It is my understanding that these meetings have afforded a real opportunity for the teachers to become acquainted with certain important phases of industry.

Perhaps more important still from this particular point of view are the Summer Conferences for Professors which some of the industries have held. These conferences have great possibili-

ties in providing engineering teachers with precisely the contacts and information which they regard as of most value in their college work, because that is the objective around which the conference programs are framed. The professors have the opportunity to discuss among themselves and with engineers and executives in industry the problems which they face in their teaching work. These programs, in other words, are different from most of the other forms of contacts referred to in that they are organized for the specific purpose of giving the members as much information and as thorough acquaintance with industry as it is feasible to crowd into the time allotted, whereas the other contacts have some other general purpose, with the objectives here under consideration as of perhaps secondary importance.

Another form of contact is employment during summer vacation, or for a longer period during sabbatical leave. In these, especially in the latter, the teacher takes up some regular engineering work, and, for the time being, becomes a regular employee. Although he may thus miss some of the broader aspects of the activities in industry with which members of a Professors' Conference become acquainted, he nevertheless becomes more thoroughly acquainted than they with some special phase of engineering. Naturally he also becomes much better acquainted with fewer individuals. In other words, working as an employee, the scope of both his activities and contacts is relatively more specialized, yet, at the same time, more thorough.

Still another rather special form of contact is the association with industry from time to time in connection with engineering or research problems, toward which he may be in position to make a contribution. A reasonable number of such contacts seem to me highly desirable both from the point of view of the teacher and industry, provided two essentials are recognized. One is that, from the point of view of the educational institution, the time and effort expended upon such work should not interfere with the efficiency of the teacher's educational work. The other, from the point of view of industry, is that the professor's contributions to the solution of such problems should justify the arrangement. Where these conditions are met, such practical contacts would seem to be helpful to the teacher in his educational work also.

Turning now more specifically to the activities along these lines as conducted by the industrial concern with which I am associated, the following table indicates the extent to which this organization has participated in such programs during the last three years.

Summer	Engineering Depts. and Test	Research Laboratory	Professors' Conference	Total
1927.....	14	3	23	40
1928.....	16	6	25	47
1929.....	24	14	24	62

I think it is in order to mention one problem which is encountered in the administration of these activities. The number of applicants for the Professors' Conference and for summer employment, etc., exceeds very greatly the number of opportunities which are available. It is thus a difficult matter to determine to whom the available opportunities will be accorded. Naturally, in the case of the Professors' Conference, it is attempted to have, in any particular year, as wide a representation from different institutions as possible; and then, over a period of years, to include all of the technical colleges.

As to positions during summer vacation or during sabbatical leave, these are determined in individual cases upon the basis of available openings at the time along the particular lines in which the teacher may be interested. Thus the character of engineering assignments in this connection varies over a very broad range.

In addition, I should like to mention one plan which may be of interest. In conducting the Advanced Course in Engineering (which comprises post-graduate training of an advanced character to a highly selected group, extending over a period of two or three years) we need competent assistance. We have found that, in addition to the engineers who are regularly occupied in carrying on this work, it has been of great value to us to have one or two professors assist us, who are on sabbatical leave. In this arrangement they spend part time on the Advanced Course work, and the remainder on some development engineering in coöperation with some one of our leading engineers. From our point of view this has been highly satisfactory in that we are given the benefit of the teachers' advice and experience in educational work; and the professors who have participated in this program have assured us that it has been very valuable experience for them.

From all of the foregoing, it is clear that Industry is recognizing the desirability of affording engineering teachers the opportunity to become familiar with the industrial atmosphere, acquainted with practicing engineers, and to acquire engineering information which may be helpful in their teaching work.

THE RESPONSIBILITY OF THE ENGINEERING TEACHER *

WILLIAM E. WICKENDEN

President, Case School of Applied Science

A famous preacher was once asked why he always began his sermon with a text. He replied that he had found it a good plan to give his audience at least one thing worth remembering. Accordingly, let us take a text. In the *Educational Record* for April, 1928, a committee of distinguished educators named by the American Council on Education to consider the problem of enlistment and training of teachers raised the question "What does a college teacher do?" A tentative answer was formulated under thirteen heads as follows:

1. Masters the subject to be taught.
2. Organizes the content in proper perspective.
3. Adjusts it to the college and the curriculum.
4. Studies the needs, capacities, interests and aspirations of the students.
5. Defines the specific values they should get from the work.
6. Inspires them to want to get the values intended.
7. Appraises student achievement and compares results with those of others.
8. Weighs the evidence and improves instruction.
9. Coöperates with colleagues in maintaining morale and in administration.
10. Discovers significant relationships among thoughts and things.
11. Develops a coherent vision of progress.
12. Creates tools that make realization of the vision possible.
13. Etc., Etc.

A text may be likened unto a gate; one may swing on it or he may pass through it. Most of the program of this school can be classified somewhere under the first nine of the above heads. The speaker, it might seem, was expected to enlarge upon the last four, with special emphasis, perhaps, on the item "Etc., etc."

Teachers of drawing have had an important place in engineering education from its beginning. The first engineering school

* Condensed Version of a lecture delivered at the Engineering Drawing and Descriptive Geometry Session of the Summer School for Engineering Teachers, Carnegie Institute of Technology, Pittsburgh, June 19, 1930.

was organized in the office of Perronnet, chief engineer of bridges and highways under Louis XV of France, in order to assure the training of a corps of engineers, designers and inspectors who could work together under common norms and conventions. The presiding genius of the Ecole Polytechnique of Paris—an institution that has left its mark on every engineering school in every land—was Gaspard Monge, the inventor of Descriptive Geometry. Gen. Thayer brought the influence of Ecole Polytechnique to West Point in 1817 and Prof. Greene to Rensselaer in 1846, and from these two sources it has radiated to all our engineering colleges. The older a usage, the less likely it is to be called into question. Descriptive geometry has held its place in the engineering curriculum for a century and a half, and while it has yielded time for other purposes, under the constant pressure of an expanding scheme of studies, there has been remarkably little questioning of its grounds for inclusion. Engineering educators have been disposed to grant its claims to value as a rigorous intellectual exercise, as a means of developing and organizing the student's powers of visualization, and as a discipline in precise representation of spatial relations. Language and ideas have very intimate relations; grammar is more than a body of conventions, it is in fact the logic of language. The same principles hold for the language and ideas of space and form, and descriptive geometry has seemed to rest secure on its premises as the grammar of spatial representation.

Every one knows that the rôle of formal grammar in the teaching of verbal language has been greatly modified. Grammar still has its technical value to the specialist in language, but a good teacher now seeks to make it an instinctive background, rather than a conscious objective in all teaching for general uses. Direct and natural methods of language teaching have largely replaced the old drill, greatly to the average student's pleasure and profit. One notes a relatively faint-hearted movement in the same direction among teachers of graphics. I am not venturing to advocate such a policy. My first point, however, is to urge the responsibility of the teacher to take an actively critical attitude toward the assumed or traditional values of his subject and his methods. In candor, we must admit that the value of descriptive geometry as intellectual discipline or as training in three-dimensional visualization is highly presumptive. Of unmistakable proof we have little. We do well to remember its French origins and to allow for the traditional French penchant for abstract intellectual discipline. The road toward proof or disproof of its specific values is beset with difficulties. We do not even know whether what we call the power of visualization is a unitary or a complex psychological trait, how this

trait or traits may be differentiated, identified and measured. Most of the tests of visualization which have been suggested are strongly colored by memory or by tactual perception. Because the road to proof is difficult, it ought not to be avoided. This is especially true of a subject of comparatively finished character. Men who are pioneering in a growing branch of knowledge may be excused for a somewhat uncritical attitude toward its intrinsic values. But growth in the science of graphics is not marked. Psychologists have taken little or no initiative in the study of visualization since Galton. Initiative waits on teachers of graphics.

My second point is that teachers of graphics have a larger responsibility than they have accepted for the entire educational process as it relates to form and space. The teaching of plane and solid geometry in secondary schools is under fire, as it deserves to be. Please do not assume that I am advocating any further reduction in mathematical training in our high schools—God forbid! But so much of the conventional teaching of Euclidean logic is sterile, considered as a science of form and space, that one wonders why college teachers complain so much of the neglect of geometry rather than putting their minds to the development of some substitute of greater functional value than the traditional courses. If one of this group were to approach a professor of education having a special interest in secondary mathematics, with an offer of collaboration in this field, it is a safe guess that he would be welcomed first with incredulity, then with enthusiasm.

These suggestions point to what seems to the speaker to be one of the chief personal problems of the teacher of graphics—that of finding an adequate field of personal initiative. If you all try to write textbooks, you become like that fabulous land where all the people lived by taking in each other's washing. Your subject is not actively growing. Its research possibilities are almost wholly educational in character, such as the critical evaluation of objectives, content and methods, the measurement of aptitudes and attainments before and after taking, the effort to gain economy of time and effort in reaching certain defined objectives and the like. If these do not appeal, the teacher must turn to some collateral features of his work.

Let us consider briefly three such collateral fields—(1) the personal counselling and guidance of students; (2) teaching, research or practice in technical fields closely related to the fundamental work in graphics, such as mechanism and machine design, graphic statics and structures, etc.; and (3) the study and teaching of the aesthetics of design. All these possibilities seem highly promising to the writer. In any case, if the teacher of graphics

wishes to rise in status and salary above a routine level he must have some sphere of initiative. However we may dislike it, the fact remains that the teacher who devotes his whole effort to perfecting himself in the art of teaching a relatively finished subject faces certain real limitations. Where may he seek outlets for his powers of growth?

The teacher of graphics occupies an exceptional position relative to new students. He is the first contact point in college with the distinctly technical and professional side of the student's work. For many of them, his subject represents the first real test in the student's experience of precise, objective standards of excellence and of economy of time and effort in planning his work. I am convinced that no well organized industrial concern would expect novices coming directly from high school to make such radical readjustments in the volume, and quality of their work as we expect of our entering freshmen, with so little guidance and supervision. The typical engineering course represents from a fifth to a third more work than the typical arts course in volume. Standards as well must be more rigorous if the student is being trained to carry in his work heavy risks of life and investment than if only his own personal development is at stake. The major problem of the freshman is that of planning his work efficiently. Nearly all that we require of him could be covered in an 8-hour day under good management. Would it be better to put all our freshman work on an all-day time schedule, provide each student with a regular work place under the continuous supervision of a definite department, and devote our major effort to efficient planning and execution of work? The present plan is defended on the ground that it trains the student to work independently. I question that —does it not merely throw the student overboard on the plea of teaching him to swim? Why try to teach independence before one knows what efficient work is?

If this plan were to be adopted a *properly staffed* department of engineering drawing might be almost an ideal supervisory force for the freshman year. Each student would have a drawing desk for his headquarters. Two class sections, about fifty students in all, might occupy a room under one supervisor, who would also be their teacher of graphics. Teachers of mathematics, chemistry, English and the like would teach much as at present. Every teacher of graphics, under this plan, would need to have many of the qualifications and interests of a high class personnel man. He would need to be skillful in diagnosing causes of bad adjustment. He would need to know a good deal about the work of all other freshman departments. He should have staff assistance from a

real educational clinician, some one who could find out what is specifically wrong when an apparently bright boy is doing poorly. Given some such set-up, we might greatly reduce freshman mortality and hand on to the second year students who know how to make their work count. There would still be three years to train the student to work under his own direction.

The second suggestion—that the teacher of graphics engage in teaching, research or practice in some related technical field—explores a radically different path. If pushed to its extreme end it might tend to reduce the departmental organization for engineering drawing to little more than a framework, with much of the personnel drafted for this service on a part-time basis from other departments. The weaknesses of the plan are fairly obvious—divided interest and responsibility, expectancy of advancement in other directions and highly decentralized supervision of freshman work. On the other hand the liaison between the drawing department, viewed as a service organization, and the technical departments would become more intimate. Taking a less extreme position, many of the advantages to the teacher and college could be gained if the teacher were to give one out-department course and carry on active research or practice in that field. Still another plan would be to include in the staff of the department of drawing one or more of a not uncommon type of draftsman—not highly trained professionally, but an artist in his way—who would have much the same status as the shop instructors and teach the practical side of the subject where skill is an object of some importance.

The third suggestion for a field of initiative—the study and teaching of the esthetics of design—is meant for occasional individuals rather than groups. The time is not far distant when all engineering schools must give more positive attention to matters of taste and beauty. In a conference with a number of officials of one of the largest of our manufacturing companies, the speaker recently raised the question of beauty of form and line as a selling point for purely utilitarian machines. The response showed a surprising interest in what may be called the architecture of machines. This subject, by the way, is a regular requirement in certain continental engineering schools. There are good reasons for urging this subject on engineers, rather than going outside to engage an artist for special lectures. What engineers strive toward, a bit blindly sometimes, is functional beauty—a beauty like that of the axe handle which represents perfect adaptation to its use. This rather than decorative art is the real field of opportunity for the teacher of graphics, but some notion of critical considerations of a purely

artistic nature ought to be given to every engineering student.

The main point, to which we return, is the responsibility of every engineering teacher for having some field of initiative outside of the artistry of teaching as such. Long experience shows that without such initiative the teacher in time ceases to grow. A non-growing teacher is unable to inspire growth in others; in fact he tends to become a drag on progress.

Every engineering teacher is concerned with gaining a more adequate scale of compensation. In the present economic order men receive what is presumed to be the market value of their services. "Market value" is a loose term, especially where professional services are concerned. There are no daily quotations, no trading recorded on the "big board." A few controlling influences are commonly recognized. Such services may have a "rarity value," as in the case of a Caruso or a Houdini; or an "emergency value" as in the surgical clinic of the Mayo brothers! or a "prestige value" as in the charges of socially prominent portrait painters; or a "cost-of-preparation value" as demanded by numerous medical specialists. It is next to impossible to invest college teaching with any of these income raising qualities, especially in the more conventionalized subjects. Good teaching is taken for granted, and distinguished teaching is so rare that the scales of rewards seem scarcely to allow for its existence. If most of us are to advance, it must come through advance in the scale as a whole.

Outside of technical fields the realms of initiative to which every ambitious teacher is pointed is research. This policy, I am convinced, would be unduly narrow for an engineering college. There are at least four fields of activity collateral to teaching which we ought to recognize as of equal worth: (1) research in scientific or technical realms; (2) original contributions to engineering practice; (3) outstanding service to the engineering profession in its organized capacity; and (4) contributions to our knowledge of educational problems and their solutions which can be passed on and applied by other educators.

One of the responsibilities of every engineering teacher is to make learning inviting to his students. By this I do not mean to sugar-coat it, but to develop in the student an appetite for learning in its pure state. This end must be accomplished largely by personal influences. The student must discover in the teacher personal qualities of a highly desirable type that he will consciously or instinctively link with what the teacher is trying to give him. Unfortunately some of the most learned men are in their personal qualities poor salesmen for learning. In a real sense, the teacher is the goods in his own show window. We all know of a self-conscious culture which repels red-blooded men, but breadth of

interests, vividness of personality, alertness of mind and a keen relish in living make an instant impression on the student in favor of the type of learning a man professes. A taste for learning grows from one's sense of accomplishment. The thing every bewildered and wavering freshman needs, more than anything else, is a taste of successful achievement. An able educator once remarked that he had learned the most important lesson of his life as a teacher in a school for the feeble-minded; it was that good education consists very largely in celebrating successes. One wonders if our rigorous engineering discipline gives the student enough chances to celebrate successes. Every engineering teacher, too, has the responsibility of inculcating ideals of excellence and accuracy, to which the high school graduate of today is so often a complete alien. The battle of morale is largely won or lost in the freshman year and the teacher of graphics is in the best position as strategist, both in his contact with the student and in the objective character of that which he gives the student to do.

My final point is, confessedly, the vaguest and most idealistic of all, namely the responsibility of the engineering teacher for outguessing the future in the development of the engineering profession. If the profession is to gain in public responsibility and influence, it will be almost wholly because of the qualities of the men it enlists. The question is three-fourths settled, positively and negatively, in the secondary schools and in the freshman year in the colleges. The first real interpreter of the profession most engineering students meet is his freshman teacher in drawing. No matter how well he knows and teaches his subject, if he knows and teaches only his subject he will only half fulfil his obligations.

GETTING STUDENTS TO STAY TAUGHT*

By FRANCIS T. SPAULDING

Associate Professor of Education, Harvard University

Students as a type, whether they are students of engineering or of any other subject, are likely to have at least one presumably deplorable attribute in common: once taught, they do not stay taught.

The study of education has concerned itself at some length with the problem of how to insure students' retention of what they have been taught. It has investigated instances in which students have learned and have remembered what they learned. It has investigated other instances—much commoner in the experience of most teachers—in which students have learned and have promptly forgotten nearly all they knew. Out of its investigations it has drawn certain generalizations which, though they do not bring to light any sure way to make students stay taught, do at least go far toward explaining why students sometimes stay taught and sometimes do not.

The generalizations in question are usually called the laws of learning. In all, there are perhaps seven or eight such laws which are recognized by prominent writers in education. I propose to discuss some of the implications of three of these laws—the three laws which are at the same time both most generally recognized and most directly concerned with the problem of getting students to stay taught. These three are ordinarily called, in the language of educational psychology, the law of readiness, the law of exercise or repetition, and the law of effect or satisfaction. Couched in thoroughly academic terms they seem, as perhaps is fitting, to carry no very direct suggestion as to what they may be good for in determining methods of teaching. Hence I shall attempt to phrase them in such a way as to indicate their bearing on the problem of getting students to stay taught. Thus presented, they may, perhaps, make possible a number of reasonably practical conclusions, not as to how teachers may secure perfect and permanent retention of all the things they teach, but at least as to how most teachers may measurably improve their chances of doing so.

The first of the three laws which is of special significance in this connection—the law of readiness—states, in effect, that *students tend to retain what they are taught in proportion to their own feel-*

* Summary of a discussion presented at the Civil Engineering Session of the Summer School for Engineering Teachers, Yale University, July 2, 1930.

ing of desire to learn it, or of need for learning it, when it is first presented to them. This is substantially a statement of the thesis which was advanced in the preceding discussion of the problem of getting students to learn.* The various schemes which were there considered for awakening students' active interest in learning—development of interest in subject matter, use of extrinsic appeals of various sorts, resort to coercion—have an important bearing not merely upon the task of teaching students in the first place, but also on the problem of getting them, once taught, to stay taught. The law of readiness carries, however, certain implications which were not directly touched upon in the earlier discussion. So far as these implications concern the teacher's task in getting students to stay taught, they may perhaps be fairly stated in the form of two explicit rules.

The first rule is a negative one: *Do not expect students to retain accurately and permanently subject matter which they have seen no "sense" in mastering.*

Students do occasionally, it is true, hold fast to knowledge or habits or skills which they have mastered merely because mastery was required. There is probably more than one adult, otherwise guiltless of any recollection of the formal geometry which he studied in high school, who can recall accurately and without hesitation that "if two triangles have two sides and the included angle of one respectively equal to two sides and the included angle of the other, the triangles are congruent"—and who can recall also that the theorem used to have an unspoken supplement in his mind: "What of it!" But accurate and permanent retention in such cases as this seems to be the exception rather than the rule.

Hence from the teacher's point of view the task of getting students to stay taught involves first of all the task of getting them to see some sense in learning. How to get them to see sense in any particular item of learning is a question to which this first rule gives no direct answer. The rule does, however, offer one positive suggestion, as well as a negative one, to the teacher. If, in the case of any given group of students, the teacher cannot get the students to see sense in the learning which he is asking them to do, then at least one of three things is likely to be true. Either the subject matter in question is something which the students do not as yet actually need to learn, or it is something which they do not need to learn at all, or the teacher in question is not qualified to teach that particular item in his course. In any case (this is the suggestion which the rule implies), that subject matter would better be left untaught by that particular teacher, in favor of something against which the odds are less great that it will never be truly learned.

* JOURNAL OF ENGINEERING EDUCATION, November, 1930.

To most teachers this suggestion is inevitably a disturbing one. It reflects darkly, by implication, on much of the teaching that is now going on in our schools and liberal arts colleges. Formal mathematics for students who perceive in it merely a detested stepping-stone to college entrance; laboratory science which seems to have as its goal only so many "experiments" duly checked by the teacher; college courses in foreign language required of students to develop superficial command of a language which they expect (and often swear) never to use—these are examples of things which have so little chance of staying taught that under the circumstances they might better not be taught in the first place. Whether there are many such things in the engineering curriculum I do not know. But in the light of what seems to be true of other fields, I suspect that it would be worth the while of engineering teachers to scrutinize their own courses in terms of this negative rule implied by the first law of learning. Does each item in each engineering course represent a real need which is seen and understood by the students for whom the course is planned, or are there many items, as in other fields of teaching, which have no sense from the students' point of view? Of these latter items the teacher may well beware: except as he can get his students to see sense in them, time spent in teaching them is likely to be time largely wasted.

The second explicit rule suggested by the first law of learning is a positive one: *Teach knowledges, habits, and skills after the students first need to use them, rather than before the need arises.* This rule obviously offers more immediate help to the teacher than does the first one. Yet, like the first rule, it carries certain negative implications; so that in considering its bearing on the task of getting students to stay taught one must properly take into account at least one type of teaching which it condemns as well as certain other types of teaching which it approves.

It condemns the type of teaching in which the teacher sets himself up as the sole or chief defender of the need for learning. Knowledge acquired merely because a paternal teacher or school promises that it will bye-and-bye be useful is knowledge which has little chance of being retained. Curricula or courses or even single units of subject matter, "learned" in response to a promise of some more or less distant future value, are likely to represent impedimenta which the student sheds as rapidly and completely as he dares.

Nor is teaching based on a promise of future value made effective merely because the promise may have some foundation in truth. One may grant, for example, that students in foreign-language courses can make extensive use of a knowledge of the ele-

ments of grammar; but students in earlier English courses seldom master the subjunctive effectively merely because they have had this truth impressed upon them. One may grant also that broadly educated persons ought to have some acquaintance with the beauties of antiquity; yet few high-school students succeed better with their mastery of Latin either because they are told that Latin is beautiful or because they are reminded of the desirability of becoming educated. One may even more readily grant that students of engineering will doubtless have important use for a knowledge of solid geometry; but the demonstrative geometry taught in our high schools and required as a prerequisite by many engineering schools seems to "stick" no better on that account. In all these cases and in countless others, the mere fact that students have been told of some future need for the subject matter presented in their courses is likely to be of little weight in producing lasting retention of that subject matter.

Here again I do not know the extent to which the first law of learning may reflect on the curricula in engineering education. Technical and professional schools in general are perhaps less guilty of flagrant violations of this law than are schools and colleges of the traditional academic type. Yet even among professional schools the tendency must inevitably be strong to teach the things that the students need to learn simply on the ground that the students need to learn them, without any great deference to the students' own convictions or lack of convictions in the matter. Hence teachers of engineering, in common with teachers of other technical and professional subjects, would doubtless do well to examine their own practice with respect to the way in which they attempt to convince their students of the value of their teaching, as well as with respect to the convictions which their efforts carry.

Consistent observance of the rule that knowledges, habits, and skills should be taught *after* students first need to use them demands, however, more than simple avoidance of undesirable practices. If the rule is to be applied effectively, the teacher must take positive steps to see that his teaching and his student's recognition of the need for learning come in close succession one to the other, and that the latter comes first.

There is a certain group of thinkers in education—a group who have been responsible, among other things, for the development of some of our most "advanced" schools for young children—who propose a striking method for seeing that pupils are taught after they realize the need for learning. The method is as simple as it is striking: it consists merely in teaching nothing until the pupils themselves ask to have it taught. In one well-known school which

adheres to this method, each pupil is taught to read, for example, not at any set point in his school career, but at that particular point, no matter how early or how late it may come, at which he himself becomes so imbued with the desire to read that he positively wants to be taught how to do so. Thus some pupils acquire skill in reading at five or six years of age, while others are left contentedly unable to read a single word until, when they are twelve years old or so, they stumble upon the idea that the ability to read is actually an ability worth attaining. The school notes with pride that by the time they are fourteen or fifteen years old the children who have only recently begun to read have acquired a facility in reading quite as great as that of the children who have been reading with ease and satisfaction for years.

The results which are reported from the use of this scheme of teaching illustrate, perhaps, the effectiveness of interest in producing learning. But the scheme itself represents, from at least one standpoint, a pitiful sort of arrangement. It seems to be based on the assumption that what pupils are interested in, and whether they are interested at an appointed time in the things the teacher elects to teach, are matters quite beyond the control of the teacher. It would seem to reduce the teacher's function, indeed, to little more than that of guiding pupils' efforts whenever, and in whatever direction, the pupils may providentially happen to want to put forth any efforts. It quite ignores the fact, amply demonstrated by skillful teachers everywhere, that the teacher himself may with forethought become the special providence which causes pupils to want to learn, and that the teacher thus has it very largely in his power to determine not merely *what* pupils shall want to learn but *when* they shall want to learn it.

Hence the rule that students should be taught any given item of subject matter after they first need to use that subject matter does not mean that the teacher must be a slave to immediate circumstances in the lives of his pupils. It does mean, on the contrary, that the teacher must adopt some definite plan for getting his students to need (and to see that they need) to do the things he wants them to learn to do.

How this may be accomplished may be illustrated in terms of a procedure instituted a few years ago in the Harvard Graduate School of Business Administration. The Business School found itself confronted each year with a group of entering students who were serious in their desire to become competent in business administration, but who had only the vaguest conception of the kind of preparation which adequate training for business must necessarily involve. These students wanted from the outset to find

themselves engaged in solving "practical" business problems. They objected, either openly or tacitly, to the study of the fundamental business principles—accounting, business statistics, finance, industrial management, marketing—which the School requires of all its first-year students: such principles, from their point of view, were well enough as matters of interest to the abstract scholar, but for the practical business man they got almost nowhere. After some experimentation the School has apparently succeeded in meeting the plea of these students for "practicalness." It has done so not through lectures on the future value of an understanding of business theory, still less through changing the content of its required courses, but simply through its method of introducing those courses. At the beginning of each year its first-year students are given as their initial assignment a thoroughly "practical" and at the same time exceedingly complex problem in business administration for solution. Each problem thus used is so presented as to be recognizable immediately, even to the layman, as one which is likely to occur commonly in business practice; yet each problem is also of such a nature as to be entirely baffling to anyone who lacks training in fundamental business principles. The students have this introductory problem explained to them; they are given suggestions as to the use of reference materials bearing on it; they are granted an amount of time for its solution which doubtless seems to them ample at the outset. They go to work upon it, and as a rule the harder and more intelligently they work the clearer it becomes to them that they are quite incompetent to reach a solution. Their realization of their own incompetence is increased by what happens to the tentative solutions which they may propose. At the meeting at which their reports are discussed, the instructor who has made the assignment takes pains to show just how inadequate their proposals have been. He takes pains also to show why the proposals are inadequate—to point out in specific instances the need for an understanding of fundamental business theory—accounting, business statistics, finance, industrial management, marketing—before any intelligent attack can be made upon the problem with which they have been wrestling. As a result of this introductory confusion the School has found that its students tend to undertake their study of these fundamental subjects with the same sort of avidity which they had previously shown for supposedly more "practical" problems.

In terms of education in general, and not merely training for business, the method here illustrated consists in confronting students with a situation which can be counted on to be interesting and significant from their point of view, and which demands their use

of knowledge or habits or skills which they have not thus far acquired. The method can be made effective through various other means than through the use of such problems as those employed by the Business School. Examinations of students' knowledge or ability in matters of obvious consequence to them, given before these matters have been taken up for formal study, may accomplish a similar result. Demonstrations of valuable skills by the teacher —skills in computation, in drawing, in mechanical operations of various sorts—will frequently awaken in students an ambition to possess themselves of corresponding skills. Statements or demonstrations by the teacher which disturb students' settled opinions, but which the students are unable to evaluate without further knowledge, will often lead to a search for such further knowledge far surpassing in the permanence of its effect the results of the most carefully planned formal assignment. Through any of these means the serious student may be awakened by a skillful teacher to a feeling of his own need for learning specific things (assuming always that these things truly need to be learned), at whatever point in his development may be reasonable. For the teacher of engineering subjects, as for the teacher in other fields, the use of these means may thus represent an important approach toward solution of the problem of getting his students to stay taught.

These, in general, are some of the implications of the first law of learning. These implications can be summarized, in a sense, in terms of the two rules for teaching which that law suggest: do not expect students to retain subject matter which they have seen no "sense" in mastering; teach subject matter after students first need to use it, rather than before the need arises. It is obvious, however, that rules of this sort cannot be merely mechanically applied. To present subject matter in such a way that students may see real "sense" in mastering it calls for a thorough understanding not only of subject matter and of students but of their relationship to one another. To awaken students' appreciation of their own need for specific items of subject matter demands skill in the use of a highly complicated technique. The first law of learning is only too evidently not an easy one to apply. Yet the rules which it suggests may, perhaps, serve as criteria by which good practice in teaching may be told from practice which is less likely to be good, and may thus offer a measure of guidance in getting students to stay taught.

The second of the laws which have important bearing on the present discussion is the law of exercise or repetition. The law of exercise states, in effect, that *students tend to retain what they are taught in proportion to the frequency with which they use it.* This

is a simple enough statement—to most persons doubtless almost a self-evident one. But certain students of education have sought, through controlled investigation, to explore the validity of this statement, and in the course of their investigations they have reached a number of significant conclusions which are by no means directly apparent in the bald wording of the law. These conclusions have to do in part with the process of learning, in part with the equally important process of forgetting.

People learn, apparently, according to a fairly well-defined "curve." This curve is graphically represented, in the case of a given learner who is acquiring some specific type of skill, by recording the results of regular tests of the learner's growing proficiency as the learning goes on, and plotting units-of-skill-acquired on a vertical axis against units-of-time-spent-in-learning on a horizontal axis. Curves of learning have been thus plotted for many skills and for many learners. No two such curves are exactly alike: curves differ both for the same learner in different skills and for different learners in the same skill. No single curve is ever entirely regular, moreover, since various things which are by no means clearly understood seem to exert marked effect on a learner's progress from day to day. Yet in spite of discrepancies and irregularities in detail, the general shape of all learning-curves seems to be the same. The curves almost always rise very rapidly at the beginning of the learner's attack upon something which he is learning for the first time, ascend more and more gradually as learning progresses, and become eventually almost horizontal. They suggest, that is to say, that a law of diminishing returns operates with respect to learning just as such a law seems to operate in many other fields of human activity.

People apparently forget, likewise, according to a curve. When a student has developed a given skill to a certain degree of proficiency, and then suddenly abandons all practice in the skill and ceases to make use of what he has learned, his acquired proficiency apparently begins to fall off immediately and in large amounts. But like the curve of learning, the curve of forgetting "slows up" gradually, until at length it also becomes nearly horizontal. Thus in theory, at least, while students must be expected to forget rapidly and extensively after initial practice has ceased, they may be counted on never to forget quite all they have learned—though in fact it is often exceedingly difficult to find any trace of the modicum which theoretically they must have remembered.

Considered by themselves, the typical curve of learning and the typical curve of forgetting are interesting but of no very obvious significance. When they are placed side by side, however, the importance of what they imply becomes immediately apparent.

Suppose, for example, that a teacher wishes to develop in his students a certain degree of proficiency in the use of a mathematical formula. In terms of tests which the teacher can employ, the desired degree of proficiency is represented by a score, let us say, of 80. The teacher presents the formula to his students, starts them on a type of practice which leads to increasing skill in the use of the formula, and keeps them steadily engaged in this practice until they can attain the required score. Then he allows the practice to stop, and passes on to the development of some other skill. But then also the curve of forgetting appears. Each student retains his 80 for only the briefest possible time: with practice no longer required of him, he loses his skill both quickly and (for all useful purposes) completely.

Clearly practice must not be permitted to stop. Suppose, therefore, that after a brief interval the teacher provides for further practice and brings his students again to the 80-mark before launching on some new learning. Once again they forget; and no matter how often the teacher may resume the practice, so long as he insists on their attainment only of the minimum desirable degree of skill, his students will never for any appreciable length of time hold fast to the necessary mastery of that skill.

The moral to be drawn from this example is not at first sight an encouraging one. Students are bound to forget, no matter how often they are re-taught—that would seem to be a fair conclusion. That is, indeed, one conclusion which the teacher must bear constantly in mind; but fortunately it is not the only conclusion to which observation of the curves of learning and forgetting gives point. There are certain other implications of quite equal significance which become apparent from a study not of the curves of first learning and first forgetting, but of the curves of subsequent re-learning and re-forgetting.

When a student has learned and forgotten and then begins to re-learn, the curve which marks his second progress differs from the curve of his original learning. The amount of skill which he has lost through forgetting comes, so to speak, from the upper end of his original learning-curve: it was first acquired rather gradually, as the curve of original learning began to flatten out. But in his re-learning of this lost amount of skill, the new learning-curve rises more rapidly than did the original curve for this same increment. Each succeeding curve of re-learning, moreover, rises still more rapidly than the first, so that less and less time is required after each forgetting to gain once more the skill which has been forgotten.

Each curve of re-forgetting likewise differs from the curve of original forgetting Where as the original forgetting took place

very rapidly, each succeeding forgetting is represented by a curve which descends more and more gradually. Hence, after each succeeding re-learning, a longer and longer interval will pass before the student has forgotten any given amount. With a sufficient number of re-learnings, indeed, the student's final curve of forgetting may become so gradual that he never forgets quite all of this given amount.

If, therefore, the teacher will set a standard of proficiency for his students not just at the level which they will need to keep permanently, but somewhat above that level, there is hope that a series of re-learnings to make up for the inevitable forgettings may eventually leave the students with the necessary residue of proficiency firmly established. Suppose, for example, that the teacher in the original illustration were to require his students to attain a mark not of 80 but of 90 as a measure of the proficiency gained through first learning. Suppose that he were then to check their loss through forgetting until he found that their scores had sunk to the minimum desirable 80. He might then provide for further practice—re-learning—carried far enough to restore them to the original proficiency of 90. Once more they would forget, less rapidly than at first, till they reached 80; once more he might restore them, more rapidly than at first, to the 90-mark. Thus with repeated periods of practice, occupying shorter and shorter lengths of time and occurring at increasingly greater intervals, he might eventually bring it to pass that his students remained more or less permanently above the 80-mark, though their proficiency might never, except for brief periods, be as high as 90.

It will doubtless be evident, even from this brief description of the curves of learning and forgetting, that the investigation of the second law of learning has made possible a number of conclusions which are of much significance to teachers. I shall attempt to summarize these conclusions shortly. But before doing so I should like to point out a curious phenomenon, common in elementary and secondary schools and no less common, I suspect, in engineering schools, for which these curves of learning and forgetting seem to offer a convincing explanation.

The phenomenon consists in the widespread conviction on the part of teachers at any one level of a school or school system that the teachers on the levels below them are doing reprehensibly slipshod work. The conviction that elementary schools offer miserably poor preparation for the secondary school is almost everywhere prevalent among secondary-school teachers; the conviction that high-school graduates are exceedingly ill-prepared for college work is apparently one of the fundamental tenets of most college

faculties; the conviction that beginning courses in nearly every school subject offer but meager preparation for later work in those subjects is a common source of bitter complaint on the part of teachers of all types of advanced courses. Truly education must be in bad hands if there is justice in these widespread beliefs.

But consider a specific example of the grounds for such beliefs. A boy of normal intelligence, let us say, has been promoted from the sixth grade to the seventh grade in a public school system. He has studied arithmetic in the sixth grade, and in his studying has concerned himself extensively with the elements of percentage. His efforts have been judged so successful by his sixth-grade teacher that he has been rewarded with a mark of B—not the highest mark he might have attained, but a mark distinctly above the class average of C. He comes to the seventh-grade teacher of arithmetic at the beginning of the school year; she tests him in those same elements of percentage in which his sixth-grade teacher reported that he shone. He not merely fails to attain a score which would warrant even a sixth-grade B, but judged by the score which he does attain he "seems never even to have heard of percentage!" Surely here would seem to be a case of inadequate preparation, if there ever was one; and most teachers can speak feelingly of similar cases at every level of the school system.

Perhaps, however, the trouble does not lie wholly with this boy's preparation in arithmetic. He has had a summer vacation to contend with, and pupils are prone to forget. Reconstruct his probable curves of learning and forgetting, and see what they show: a long period of first-learning all through his sixth-grade course, culminating, let us say, in a score of 80, which stands for B; then no further learning during half of June, July, August, half of September—scores descending to 50, 30, 20, 15; and when his work begins again at the end of September a score which must inevitably look as if he had indeed "never even heard of percentage." Yet this has happened not because of poor preparation in his sixth-grade work, but in spite of the best preparation his sixth-grade teacher may have been able to provide for him—simply because pupils tend to forget things which they do not use, and to forget them quickly and in wholesale amounts.

Perhaps in this illustration will be found at least part of the explanation for many teachers' suspicion that the teachers who have preceded them have done something less than their full duty. I do not maintain that there is no slipshod teaching in American schools: there is doubtless all too much teaching which falls very far short of effectiveness. But in many instances the charge that previous teachers have done ineffective work ought properly to re-

flect not on the teachers at whom the charge is aimed but on the teachers who make it. No teacher can be expected in the course of a single year to build up in his students a large body of habits or knowledge or skills which his students will retain with unlessened proficiency. Each succeeding teacher must, therefore, teach over again many things which have already been taught. The latter teacher will find, in doing so, that the work of preceding teachers has by no means been wasted: though its results may not be apparent in what his students remember when they first come to him, these results will make themselves evident in the relative ease with which his students learn again the things they have once learned and thereafter forgotten. And the teacher who interprets his students' forgetfulness of their earlier work as merely a reflection on the teachers who have preceded him and not an obligation on himself, is giving the clearest possible evidence of his own lack of understanding of what is involved in successful teaching.

So much for this phenomenon of teachers and teaching. What, then, does this second law of learning specifically imply as to teaching method if the students are to retain what they have been taught?

It implies, in the first place, that the teacher must *arrange for a series of practice periods on each item to be mastered.* Not one practice period, nor even several, will be sufficient for mastery of most of the items of knowledge or habit or skill which are taught in our secondary schools and colleges. There must be many such periods devoted to each item, if first learning and the necessary relearning are to be adequately assured.

Practice periods seem to be most effective, experiment has shown, when they are relatively short, even at the beginning. They seem to be most effective also when they involve natural use of the item of learning in question—as, for example, in employing that item in the solution of some problem of interest to the student, or in making use of it in the acquisition of new subject matter. But even formal "drill" periods, if they are sufficiently varied in method to hold students' interest, may prove thoroughly effective in providing the essential re-learning.

The law implies, in the second place, that *practice should be conducted frequently at first, with gradually lengthening intervals between the practice periods.* How long each interval should be cannot be prescribed off-hand for all students or all subjects. Appropriate intervals can, however, be determined with reasonable accuracy for a given subject and a given group of students by the teacher himself, if he will test his students from time to time on their retention of skills which he is seeking to make permanent, and will provide practice when retention falls below the necessary level.

In the third place, the law suggests that the teacher should *require mastery of each item of subject matter somewhat beyond the point at which permanent retention is desired,* to counter-balance the inevitable effects of forgetting. Only through a measure of initial over-learning can students be got to stay permanently taught to the necessary degree.

And finally, the law suggests that it is incumbent on every teacher to *recognize that knowledges, habits, and skills previously acquired will probably not have been completely retained,* and to provide such further practice upon them as may be necessary. The teacher should plan to teach again, that is to say, the skills which his course may presuppose, even though these skills may have been taught long beforehand by some earlier teacher; and he should continue to teach them again just as often as forgetting reduces his students' proficiency in them below the level at which they need to be retained.

At this point it may be well, perhaps, to inject a parenthetical word of caution. The four suggestions which are coupled with the law of frequency in learning may seem to the casual reader to represent a complete prescription for getting students to stay taught. They do, it is true, tend obviously toward that goal, but they are by no means all-sufficient. Repetition without interest is likely to produce at best only a mechanical sort of learning which is of little practical use and which seldom "sticks." The law of frequency cannot be counted on to work without relation to the law of readiness. Nor do these two laws together seem to have full effect except as they are coupled with the third of the laws which most directly affect students' retention of what they are taught. Hence the teaching procedures suggested in connection with each of these laws represent not a variety of methods from which the teacher may take his choice, but a series of techniques no one of which can be safely neglected by the teacher who is truly concerned that his students shall stay taught.

The third law of learning—the law of effect or satisfaction—may for present purposes be considered somewhat more briefly than the other two. It states, in substance, that *students tend to retain what they are taught in proportion to the satisfaction which they derive from their eventual use of it.*

Psychologists have long recognized the importance of satisfaction in determining what people remember. It seems to be a well-substantiated generalization that one tends to recall things which have pleasant or useful associations, and actively to forget things which are unpleasant or which apparently serve no good purpose. But in spite of the general recognition of this tendency the full

importance of satisfaction as an element in learning seems to have received much less than its proper emphasis in most plans for teaching.

How important the element of satisfaction may be is well illustrated by an experiment recently conducted by Professor E. L. Thorndike of Columbia University.* The experiment consisted in having a number of persons practice blind-folded in drawing, at the command of the experimenter, lines three inches, four inches, five inches, and six inches long. Each person subjected to the experiment drew first an extensive set of such lines—600 in all—with no indication from the experimenter as to whether he had succeeded or failed in his attempts to approximate the various lengths. The results in most cases, as might have been expected, were very far from accurate. Each subject then underwent a course of "training" in drawing such lines. Still blindfolded, he practiced the drawing under the direction of the experimenter, but after each effort he was informed that his results were either "right" or "wrong"—"right" meaning accurate within a small margin of error, and "wrong" meaning correspondingly inaccurate. Here too the results were what might have been expected: the drawers improved rapidly and to a marked degree in their efforts at approximation. But then again they were required to draw a set of 600 lines with no check whatever upon their success. And in this second test the effect of the absence of any check was a notable one. Practically all the drawers fell off very definitely from the accuracy which they had attained in the practice period, and some of them lost proficiency to such an extent that their final scores were no higher—occasionally even lower—than those which they had gained before any practice whatever had been undertaken.

Satisfaction in this instance consisted solely in the check which each subject was given upon the success of his efforts. With that check supplied, practice was indisputably effective. But with the check lacking—that is to say, with the element of satisfaction entirely absent—such further practice as was supplied by the final test seemed to have no worthwhile effects whatever.

Consider, therefore, what the law of satisfaction may mean with respect to getting students to stay taught. Like the law of readiness, to which in a sense it supplies the complement, it suggests both a positive rule and a negative one.

The positive rule is an obvious one: *Provide all possible opportunities for worthwhile and effective use of each item of knowledge, habit, or skill which students have been called upon to master.* Provide such opportunities, so far as occasion permits, by putting

* This experiment is described in detail in Thorndike, E. L., and others: *Adult Learning* (Macmillan, 1928), pp. 96–100, 291–98.

the students into "natural" situations which call for the employment of the item in question, since situations of this sort are more likely to carry satisfaction that are mere formal provisions for drill. But see to it that things learned have a chance to be used, even if that chance must often be artificially arranged.

The negative rule, in the light of Thorndike's experiment, is hardly less obvious. *Do not expect learning to result from the use or practice of knowledges, habits, or skills in which students have no gauge of their own success.* The gauge need not always come from the teacher: it may frequently take the form of some standard which the student can apply quite independently. But some direct measure of success or failure is apparently always necessary before learning can be counted on to be effective. Practice alone *does not* "make perfect"; and work done for the wastebasket—work done, that is to say, without any direct check for the student on his own achievement—is at best of questionable teaching value.

Students tend to retain what they are taught in proportion to their desire to learn it, in proportion to the frequency with which they use it, in proportion to the eventual satisfaction which they derive from its use. Teachers ought therefore to awaken their students' interest in learning, to provide for adequate practice on things to be learned, to assure opportunities for worthwhile use of what has been learned.—These two statements represent in substance the gist of the best present answer (so far as I am acquainted with that answer) to the problem of getting students to stay taught. And there is little doubt that if teachers in general were to make full use of the procedures which that answer suggests, students would retain much more than they do now of the things that they have been taught.

In setting forth that answer I have necessarily been mindful, however, of the fact that to put the suggested procedures into full effect would require radical changes in most present plans for teaching. Schools are accustomed, at present, to undertake the teaching of many things and to be satisfied with only fragmentary retention of what their students have been taught. Schools in general doubtless try to teach too much, and end by actually teaching all too little. It is not hard to see why this is so: the task of securing students' retention of what they are taught is difficult and time-consuming, no matter how effectively the laws of learning may be observed; and the pressure of "ground-to-be-covered" is so great that schools and teachers in general are unwilling or unable to give all the time and energy to each single unit of subject matter which permanent mastery of such units demands. But though the

reason for the present state of affairs may be obvious, its obviousness does not lessen the difficulties which confront any teacher who tries to go beyond a mere covering-of-ground. Hence I should like to make at least a brief attempt, in concluding this discussion, to show how the suggested procedures may be successfully applied.

If under present conditions any single teacher is to teach any large part of his subject matter in such a way that his students do actually stay taught with respect to it, he must take advantage of all possible economies in learning. He must find some method, in other words, for saving time ordinarily devoted to less important matters in order to have more time to give to the task of insuring his students' permanent retention of essentials.

Such saving of time is entirely possible in much of our present teaching. Three major economies alone would add greatly to the opportunity of which most teachers can avail themselves for teaching essential things permanently. One such economy is to be found in teaching nothing which will have later to be untaught. If, for example, students must eventually perform mathematical calculations according to a given technique, then in the long run time may be saved by requiring them to practice that technique from the outset, even though a different technique is easier to teach at the beginning. A second economy may be secured by avoiding insistence on detailed mastery where possession of a usable "idea" will suffice. To bring oneself to the point at which one can understand and retain the gist of a chapter in a textbook is, for instance, less difficult and less time-consuming than to commit to memory every point included in that chapter; and the "general idea" in such a case may be quite as effective as memory of itemized details. The third economy consists in requiring mastery only in matters in which mastery is actually essential. It is almost a truism that schools seek at present to have their students master many things of which mastery can be expected to serve no good purpose. Why, for example, should students be required to distinguish three different classes of levers when thorough understanding of the single underlying principle of levers will enable them to deal adequately with any lever, no matter what class it may represent? or why should students learn one rule for finding the square of the sum of two algebraic terms and another rule for finding the square of the difference of two algebraic terms when a single rule for squaring a binominal, quite as easily taught, will completely cover both sum and difference? Through teaching nothing which will have later to be untaught, through avoiding insistence on detailed recall when an "idea" is sufficient, through teaching nothing which does not serve a purpose which nothing else will serve—by these three means

alone most teachers can secure for themselves far greater opportunity than their scheme of teaching now provides, for getting their students to stay permanently taught with respect to things which are essential.

And even with respect to essentials a certain measure of economy is possible. Students learn most economically when they learn "well" from the very beginning. Once an essential knowledge or habit or skill has been presented, therefore, its mastery should be insisted on. It should be interesting and recurrent and effectively usable—all three; but more than that, it should at no single point be permitted to be only half-learned.

These various economies will not permit everything that is worth teaching to be taught so that it will stay taught. They may, however, allow more than mere covering of ground in the case of at least the most important items of learning; and to this extent they may promote, even under present conditions, a kind of teaching through which students retain accurately and permanently the things they learn.

THE DIVISION OF COÖPERATIVE ENGINEERING EDUCATION

Committee: F. E. Ayer, D. C. Jackson, Jr., C. W. Lytle, K. G. Matheson, J. E. McDaniel, H. Schneider, E. Willis Whited, W. H. Timbie, Chairman

Starting with this number of the JOURNAL one page of each issue will be devoted to news and short articles of interest concerning Coöperative Engineering Education.

Under the direction of President Matheson, as Chairman of the Program Committee, the Division is already laying plans for its program at next summer's Convention to be held at Purdue University.

W. H. TIMBIE.

Some Coöperative students take the attitude that their sole job is to make good with their work and that their responsibilities cease when the whistle blows. To combat this tendency, we require that all Coöperative students prepare technical reports on some phases of the work of their employer twice a month. The Department of Coöperative Work arranges with the firm to have these reports read and approved by a responsible member of their organization before they are sent to the University. The fact that these reports are read by his superior, and often, in addition, by an executive, encourages the student to make them as accurate and complete as possible. This is because they affect, not only his University grade for the period of work, but also, and more important, the opinion which his employer forms of him.

We find that the employers are very glad to coöperate with us and to take the time to read these reports. In fact, many students have to rewrite their reports two or three times before they can secure this approval. Obviously, after this has happened to a student once or twice, he takes more pains in preparing his later ones.

After watching the effect, both on the student and on the employer, of requiring these reports and of having them signed by the employer, we feel that we have raised the standards of the cooperative work a considerable extent.

E. WILLIS WHITED.

REPORT OF CONFERENCE ON COÖPERATIVE ENGINEERING EDUCATION AT THE 39TH ANNUAL MEETING OF THE S. P. E. E., MONTREAL, CANADA, JUNE 26–28, 1930

RAILROAD WORK AS VALUABLE PRACTICAL EXPERIENCE FOR COÖPERATIVE STUDENTS

By J. E. McDANIEL

Georgia School of Technology

The Georgia Tech Coöperative Department was founded in 1912 with an enrollment of only a few students who could be counted on the hand. For five or six years it struggled desperately to survive when many of the older professors considered it too costly and wasteful for educational experiment. Today, or this academic year, the Department has a registration of over six hundred. This past summer over four hundred applicants were refused admission to the freshman class principally because of the rigid entrance requirements for this particular department; only students who have attained high scholastic rating in their preparatory or high schools, being at least in the upper third of their class, are admitted for the Coöperative course of study.

The alternation period is four weeks: while one section is at college the other is at work, each section exchanging the place of the other every four weeks over the duration of five years. The students have three weeks' vacation within a year, and are given the identical courses as the four-year men, with the exception of a few shop courses or a slight variation in some course to suit the needs of students who have had considerable practical experience. I wish to add that the Coöperative students do not seem to have their schedules too crowded, or to have unusual difficulty in finding sufficient time to prepare for the next-day classes. Some of the very brightest find time to participate in extra-curricular activities. The honor societies, such as Phi Kappa Phi, Tau Beta Pi, etc., have large numbers of Coöperative students.

About one hundred and fifty of the six hundred Georgia Tech Coöperative students this year voluntarily asked to have their practice work with railroad companies. For some reason or other many young men have an ingrained fascination for railroad employment. Even when they were infants they cherished the idea that when they became of age they would have an opportunity to

operate a huge locomotive. Although many such ideas may have vanished when the same young men entered college, some of them as Coöperative students are still eager to work for a railroad company.

I often feel much gratified when interviewing such students, because now so many students who matriculate for a college course are obsessed with the desire to acquire what we might call the by-products of college life. Their foremost ambition is to join some fraternity, keeping in direct contact with all the social phases of college life, or to get distinction in athletics or some of the well-known extra-curricular activities.

Some of these railroad students may indulge to advantage in these by-products, but they are not likely to over-emphasize the irrational fads and fashions of the moment. They probably will consider the habits, aptitudes, and general characteristics of the regular shop apprentice and of their fellowmen as by-products of their courses of study, thus subconsciously getting a practical insight into economics, sociology, ethics, and psychology. Perhaps the railroad student could have nothing more beneficial than this study of practical humanities which might be termed the human element of engineering. This sober, serious aspect which may characterize a majority of the Coöperative students is well worth while; the contrast of social conditions in railroad employment with those of college life will prompt anyone to consider the serious problems of civilization. With the fairly well balanced students—only the Georgia Tech applicants and students who are above the average in intelligence and bearing are admitted into the Coöperative Department—there is very little danger in over-emphasis on the sordid aspect of business found in big corporations, or more particularly in the duties of a railroad shop.

At Georgia Tech the Coöperative students who wish to follow railroad work are apportioned according to their matriculation blanks into mechanical, civil, and electrical engineering groups. The mechanical engineering students are placed in the shops; the civil in the maintenance of way and bridge construction departments; the electrical in the signal department and in the electric shop.

The railroad companies will not set uniform regulations as to the exact kind of work on which at first to place the Coöp, but generally the mechanical engineering student is started in the foundry or forge shop where he will remain three months or longer; then he is given about nine months divided between the car department and the machine shop; later about six months in the boiler shop; his fourth year in the erecting shop; and his last and fifth

year in the drafting room and in the test department. This schedule of practical work was inaugurated by the Central of Georgia Railway Company about eight years ago and is more or less carried out with several of the other roads using Georgia Tech students. However, as I said before, no hard and fast schedule of work rotation is carried out uniformly by any one road, or by several roads. The students are shifted about on the work as the road finds opportunity for adjustment. As a general rule, every graduate has found some experience in every department aforementioned during his five-year career. The last year—when the student has opportunity to take part in some design work, in testing steel, and in fuel analysis—is the most interesting according to the opinion of most of our graduates.

The electrical engineering students are placed first in the signal department where they live for a year or more in box cars along the tracks doing laborious tasks of every nature, but giving a large portion of their time to the signal installation and repair work of certain sections and divisions of the road. Their duties are to maintain transmission lines, to keep in perfect order the block signals showing the automatic color light. When new rails are laid the students often insulate the joints and help lay the track circuit. The third year the students are given some experience in the electric shop where they have duties of an electrical nature, such as general electrical repair, car lighting, armature winding, etc. Often they are given some electrical engineering experience in and around the power house. The last two years they are "put over" the drafting board of the signal department, where they make blue prints of the field work.

The civil engineering students are placed for one year or more in the roadway department where they learn to do the hardest kind of labor, such as the laying of cross ties and rails in the rebuilding of a track after a wreck, or after a washout from rainfall. The next two or three years they are given experience in the maintenance of way department where they have both field and office work. They may have to adjust any part of track which is out of line so that the curves and spirals are fitted properly. They often have to outline or map a drainage terrain in proximity to the road's right-of-way so that the proper deposition may be had at court. Frequently they will make a survey of a certain railroad crossing which becomes important evidence in a court suit, or they will have to make a survey of some side or spur track which will serve the needs of some individual or private company.

The last year they sketch the A. F. E. blanks (Authority for Expenditures), getting the measurements for anything relative to

maintenance, even such as coal, brick, and lumber bins. They also keep an outlay of all bridges on lines, showing alterations and changes on same in the field book. They record placement of floors on bridges indicating spacing, such as ties, stringers, and floor beams. The aforementioned outlined practical experience which the civil engineering student may obtain in railroad employment, also which other engineering students may acquire under the Coöperative Plan in railroad work, should be invaluable to engineering graduates.

Where do such graduates find permanent employment? Some remain in a supervisory capacity with the old employing railroad companies; others find employment in a supervisory capacity with railroad companies that have never tried the Coöperative Plan; others follow some kind of engineering other than railroad work; others do not follow engineering at all, usually getting some kind of sales work of an engineering firm.

In conclusion, I wish to say that the Georgia Tech Coöperative Department feels that both the students and the railroad company are benefited by this Coöperative Plan of education which I have tried to outline in a very brief way. I believe anyone will say that the student is much benefited by such practical experience; in fact, the old adage that "the most effective teaching is the practical work" is realized under the Coöperative Plan. As an illustration of what the Central of Georgia thinks of these student apprentices, the president of the road at the Georgia Tech commencement exercises every year delivers to the students who have completed their five-year practice program in the Central of Georgia Railroad's shops a formal certificate indicating a completion of work held in conjunction with Georgia Tech.

Discussion

R. S. King: It has been the author's pleasure and my pleasure to work with coöperative students for quite a number of years. I took particular pains to inquire of these boys just what particular good they had derived from the railroad coöperative work. The author and myself are of the opinion that these men have had a most excellent opportunity to study the human ties, if you want to call it that; in other words, human nature. The railroads present in their shops a most excellent opportunity to train the boy, that is, if he has any tendency toward pig-headedness or swelled-headedness they take it out of him pretty quickly. I think that it is certainly an excellent vehicle for that purpose.

I was rather surprised to find that the students were very much alive to the railroad questions that come up. I asked them whether

they ever entered into any discussion with their foreman or men with whom they worked, and I found that the question of the car loadings and the recapture law, and all those sorts of things, were very familiar to the student, having a tendency to bring out the economic end of railroad operation.

They also are very much alive to the present-day question of railroad shops entering into, you might say, the contract system. The tendency is for a number of our railroads to contract all of their repairs and all of that work rather than do it themselves. Some of the criticisms that have been entered against the railroad shop is the fact that the student is not fitted for modern production, that is, there is not a question of mass production there. Also, the student work in the railroad shop is rather rough, rather unfinished. Therefore, he may have some bad habits to overcome when it comes to close machine construction. However, that is not a serious bad habit.

The shop as a whole is a most excellent method to teach the young engineering student, first, organization; second, the necessity for hard work in times of stress; third, loyalty to the company for which he works; fourth, how to get out of difficulties by employing the tricks of the trade and often to make substitutions; fifth, that practice has solved many things that mathematics does not have the apparent solution for at the present time.

The mechanical coöperative student does not stick with railroad work as much as he should because the roads do not offer sufficient incentive for advancement. The idea of seniority has killed off the ambition of many who enter the railroad service. In spite of some of the above criticism, it is an established fact that the railroads offer good vehicles for coöperative education. Some of our southern roads require attendance at many instruction classes and encourage night school attendance in air-brake and such other classes. Certificates are awarded to those who finish.

THE COÖPERATIVE PLAN APPLIED TO AERONAUTICAL ENGINEERING

By F. K. TEICHMANN AND C. W. LYTLE

New York University

Orientation

The problem of orientation looms large in all coöperative work, regardless of the department. Early practical experience necessitates early consideration of each man's aims for the future. It is the experience of most of us that these aims are extremely broad, sometimes merely negative and rarely based on accurate knowledge of the profession as actually carried out. Despite this situation and although we keep our first two years of engineering identical for all departments, there is a surprisingly small amount of departmental transfer, during the undergraduate course.

The work of orientation is therefore mainly a matter of finding the subdivision of the main field which is most suitable for the individual student's qualification. The breakdown here submitted for Aeronautical Engineering, Table I, is approximately a true picture of conditions in the field and is the first thing an applicant for coöperative work needs to face. Some of the men know at once which subdivision comes closest to their qualifications and tastes, but most of them are unsure of either their qualifications or tastes and some are very inconsistent. On the other hand, those who have potential research ability will usually have a definite enough realization to allow the coördinator to accept it as probably true.

TABLE I

Breakdown of Whole Field

- Aeronautical Engineering
  - (*a*) Research
    - Mathematical
    - Laboratory
  - (*b*) Manufacture of Planes
    - Land planes
    - Amphibions
    - Seaplanes
      - Designing, Producing, Experimenting, Maintaining
        - Fuselages, Wing Structures
          - Metal work
          - Wood work
          - Textile work
        - Landing Gears or Pontoons
      - Designing, Producing, Experimenting, Maintaining
        - Accessories
          - Instruments
          - Rubber goods

TABLE I—*Continued*

(*c*) Manufacture of Engines

Designing, Producing, Testing, Overhauling — V-Type, Radial, Inverted in-line, Broad Arrow, Opposed

(*d*) Transport Operation

Design and Construction of Airports — Runways, Flood lights, Buildings

Layout of Airways
Maintenance
Routing and scheduling of service
Communication
Commercial
Financing
Accounting
Prevention of accidents
Publicity
Meteorological service

Research

We have had some sophomores who insisted on research work whom we would certainly not have sized up as research men on our own powers of observation. We mention research first, because the number of men who are capable of this are relatively few and are likely to be as definitely unsuited to the non-research side of engineering as they are suited to the research side. Men of this type have particularly good opportunities in the aeronautical field today because of its newness. They are the ones who usually take an extra year on the campus, and therefore, under our Coöperative Plan, do not take the year out in industry between senior terms.

Manufacture of Planes

The next subdivision of importance is the manufacture of planes. It is in this field that we have had the greatest opportunity for placement. Men usually start with ordinary manual work, either in the metal, wood, or textile departments, eventually rotating through all three. Those who make good sufficiently to return to the factory for successive periods are pretty sure to win promotion to drafting or experimental work. Again because of the newness of the field, drafting is a relatively larger opportunity for our students. There is no company which is not making changes in design. The ordinary employee cannot be used for this work and we find that we can place quite a number of men, even sophomores, in this work. We prefer to start sophomores on

production work so that they will be more resourceful for design when it comes later. In dull times we do, however, place beginners on drafting to avoid competition with tradesmen.

Manufacture of Engines

Up to the present, this field has not attracted as many of our aeronautical students as might be expected. The typical student yearns to fly or to get close to the plane itself. If he is primarily interested in engines he is more likely to take the mechanical course than the aeronautical. On the other hand, Mr. Charles Lawrence of the Curtiss-Wright Company has said, "We cannot afford *not* to coöperate with your Aeronautical Engineering Department." This indicates that manufacturers of engines feel the need of aeronautically trained engineers and that we may have an increasing number in this field. As in other fields, the two-year cadet course for four-year graduates will probably be shortened for coöps.

Transport Operation

This subdivision promises sometime to be the most important of all, but it is not so at present. We base this forecast on the history of railroading and other transport developments, but just when it will become the most important we cannot say. Unfortunately the high degree of hazard in aeronautics has retarded the use of undergraduate men to a considerable degree in this field. Companies operating flying lines give us two reasons, either one of which would account for their reluctance to hire inexperienced men. In the first place they usually have their own flying schools and find that graduates of these schools always furnish waiting lists for employment which the company feels somewhat obligated to meet. In the second place, these companies are so fearful of accidents that they object to employing any but experts and dare not use the job itself as a means of training. We suspect, however, that there is another reason, namely, that high school boys are taking flying courses and volunteering to fill these jobs without asking any wages! Because of these conditions we have so far succeeded only in placing men through personal contact or by getting them in through some flying course.

Options in Curricula

It is most unfortunate that the proportion of operating jobs to manufacturing jobs is so small, because we are at the same time forcing the majority of our aeronautical students into what we call the Transport Option. The alternative option is called the

Technical Option and is limited by our present capacity both in teachers and equipment. Those taking the Transport Option will be given the general courses in Aeronautics and will receive the same degree, but instead of the more technical design courses there will be given courses which were formerly segregated under the heading of Industrial Engineering. We believe we are justified in keeping the Technical Option small and also in encouraging a majority to take the business end of engineering, but we have not as yet found any way of getting the appropriate jobs for this majority. We are obliged to start most of them in factories just as we do the technical option men.

Placement

The manner of determining the subdivision most suitable to each man is in no sense different from that used for the other departments. The Coördinator indicates the break-down and draws the man out in regard to his qualifications and tastes. It is usually found necessary to do this in a series of about three interviews. The first one is general, the second one is specific, although not narrowed to a choice of any single company, while the third one attempts to narrow the issue down to the one best opportunity. Much of the Coördinator's contribution comes through his field contact which enables him to bring before the student the actual possibilities which fall within the limits of the personal qualifications and tastes. While there is some trial and error in the first placement, there is not as much of it as some might expect. Neither is it difficult to persuade the student to stay with a single company for all or most of his periods if the company is reasonably large, and fair in its treatment. There is ample evidence to the student that he is more likely to gain in promotion and to get a more complete, unified experience, than if he jumped around inconsistenly from one factory to another. While there are exceptions to this rule, we believe it is generally true that it is better to have a student gain a thorough knowledge of one company than to gain a superficial knowledge of several.

Specialization in College Comes Late

Not only are the first two years of engineering curricula identical for all departments, but the undergraduate curriculum in aeronautical engineering is identical for the first three years with that of mechanical engineering, except for one elementary course in aerodynamics and airplane design given the second semester of the Junior year. Specialization in aeronautical engineering, there-

fore, really does not begin until the Senior year.

The first period in industry comes during the summer after the Sophomore year. Although this period may determine the student's future, it is mainly intended to check his own opinions. The particular work he does is not therefore so important provided he has every opportunity for observation and absorption of aeronautical lore. In fact, there is so much for him to learn in a general way that we have sometimes accepted factory work which was not strictly aeronautical. The job should, however, be close enough to the aeronautical engineering field so that he can definitely decide whether he has been justified in electing the Aeronautical Engineering Department. The second term of work, or Junior summer, should show him which of the special courses will best meet his needs.

Example of Work

Suppose, for example, that a student finds employment in a servicing hangar at an airport. The tasks are simple and such that any common laborer might perform them, but the opportunities for an interested student to study air transport operation, aircraft structure, aircraft engines, airport personnel, etc., are unlimited. If the student is interested in aircraft design, he will soon observe whether the airplane structure is wood or metal, steel or aluminum alloy, riveted, welded, or bolted, whether the pilot, baggage, and passenger arrangements are adequate, whether the airplane is single or multi-motored, high or low wing monoplane, and all the other ramifications of the aircraft structure. All of this is drawn out by means of observation guides and bi-weekly reports.

If his interest is aroused in air transport, he will study the airport layout, the hangar facilities, the size and accommodations of planes, seating arrangements of transport planes, as well as costs and operating routine of an airway. Servicing planes will give first hand information of aircraft engines. A study of dimensions and areas of tail surfaces, wings, ailerons, etc., and of their relations to the three axes of the airplane, as well as conversations with pilots will soon indicate which plane is more manoeuverable, more stable, more efficient, and if he has any intelligence at all, he will begin to appreciate the rudiments of aerodynamic theory.

A Coöperative Class Resourceful

By his first term Senior year, the coöperative student will have a fair conception as to what it is all about. Since the more technical courses are limited to the Senior year, it is necessary to cover a great many phases of aeronautics rapidly. Classes made up

largely of coöperative men can cover this ground more comprehensively and concisely because they have a foundation of knowledge and interest. In other words, the teacher does not need to spend much time on elementary explanations.

By way of illustration, suppose a student is interested in aircraft design. He will take the technical option of aeronautical engineering and in his Senior year will make a complete design of an airplane. If he is a coöperative man he will incorporate in his design many features which he has seen at first hand during his periods in industry. He will also have the confidence to add many of his own ideas.

It is well known that any coöperative class is resourceful in the matter of recent practice developments since each man contributes from his own intimate experience. In a field as new and changing as aeronautics this is doubly advantageous. No collection of texts, certainly no one teacher, can keep up immediately with the rapid advance. A whole group of coöperative men returning to college from diversified companies can and do act as a most efficient clearing house. In reading the reports we are amused at the usual enthusiasm shown by each man for his company's designs and methods, but in class these various matters are compared and constructively criticized. Just how rich this resource is may be realized by a survey of the accompanying list of employing companies.

TABLE 2

LIST OF COMPANIES WHICH HAVE RECENTLY EMPLOYED AERONAUTICAL ENGINEERING UNDERGRADUATES ON THE COÖPERATIVE PLAN

This list speaks for itself, but we may briefly call attention to a few of the interesting aspects. It will be readily seen that the list covers every subdivision of the work, every size of company, and a considerable geographical area.

Alexander Aircraft Company, Colorado Spa, Col.
American Aeronautical Corporation, Port Washington, New York.
Atlantic Aircraft Company, Hasbrouck Heights, New Jersey.
Aviation Corporation (U. S. Aluminum Co.), Buffalo, New York.
Bellanca Aircraft Company, New Castle, Delaware.
E. W. Bliss Company, Brooklyn, New York (Jupiter engines).
Brewster & Company, Long Island City, New York (Pontoons).
Brooks Field.
Brunner Winkle Company, Ridgewood, New York.
Chance Vought Company, Hartford, Connecticut.
Curtiss Aeroplane & Motor Corp., Buffalo, New York (Engines).
Curtiss Aeroplane & Motor Corp., Garden City, New York.
Fairchild Manufacturing Corp., Farmingdale, New York.
Fokker Aircraft Corp., Passaic, New Jersey.
Gates Aircraft Corp., Corona, New York.
Great Lakes Airways, Erie, Pennsylvania.

TABLE 2—*Continued*

Great Lakes Aircraft Corp., Cleveland, Ohio.
Hall Aircraft Company, Buffalo, New York.
Keystone Aircraft Company, Bristol, Pennsylvania.
Langley Field, Virginia.
Loening Aeronautical Engineering Company, New York City.
Glenn L. Martin Company, Baltimore, Maryland.
Master Aircraft Company, Rochelle Park, New Jersey.
Mitchell Field, Long Island.
Naval Aircraft (U. S. Navy Bureau), Philadelphia, Pa.
New Standard Aircraft Corp., Paterson, New Jersey.
Nicholas-Beasley Airplane Co., Marshall, Missouri.
O'Connor Transatlantic Airways, Inc., New York City.
Pioneer Instrument Co., Brooklyn New York (Flying Instruments).
Sikorsky Aircraft Corp., Bridgeport, Connecticut.
Skyview Lines, Inc., Buffalo, New York.
Wright Aeronautical Corp., Paterson, New Jersey (Whirlwind Engine).

Last Period Important

Upon completion of the first term of the Senior year, the student is ready for the triple period, that is, one year in industry. College has perhaps crystallized his thinking and raised a great many questions which he would like to settle. He is now ready to be placed in some work definitely allied with his interests. This placement is the most important of all because it is pretty sure to determine his future. The contacts he makes during this year in industry, as well as the reputation he establishes, will usually secure him a good position upon graduation. Up to this June, every New York University graduate in aeronautical engineering has promptly secured a position in the aeronautic industry. The present depression has made it impossible to place all of this year's graduates in the field and some doubts have been raised as to the immediate future.

Close Relations Between College and Industry

The relationship between the aernonautic industry and the college is a most happy one. The industry requires a great deal of research in aerodynamics, and structures, as well as other phases of aeronautics. Coöperative students often bring problems for research back to college and these problems form the basis of excellent theses. The Daniel Guggenheim School of Aeronautics is well equipped for this research work. We have two wind tunnels, one nine feet in diameter with an attainable wind speed of 115 miles an hour, and a smaller one four feet in diameter with an attainable wind speed of 45 miles an hour. These wind tunnels are used for determining the aerodynamic characteristics of air-

craft or their component parts. These wind tunnels are at the entire disposal of the students. In fact, two coöperative undergraduates have been employed here on company research.

There is also at the College an engine testing laboratory for research work on aircraft engines, either air-cooled or water-cooled. In addition there are facilities for structural investigations of wings, ribs, tail surfaces, and fuselage structures, characteristics of shock absorber struts, and the like. Flight testing instruments and calibrating apparatus are also available. The calibre of this research work is high and the coöperative student may use it to strengthen his hold upon a position.

The employers in the aircraft industry are giving preference to men with previous experience in the industry. In fact, there is not a large supply of old experienced engineers as in other fields, all of which gives the coöperative plan a real importance.

Conclusion

It is evident therefore, that the aeronautical field has all the need of the coöperative plan which has been demonstrated in the older engineering fields. Some of these needs are greater than in other fields because aeronautical engineering is still new and developing with phenomenal rapidity.

ENGINEERING COURSES IN SCHOOL OF BUSINESS CURRICULA

By GEORGE FILIPETTI

Columbia University

Coöperative education, at least in the sense in which you are using it, has little connection with the title of this paper. An explanation of how the two were brought together would consume the fifteen minutes which Professor Jackson has so definitely set as the limit.

At the time the suggestion was made that this subject be discussed it was my understanding that the meeting was to be one of engineers only. With that in mind, I have raised certain questions which it is hoped the engineers will answer.

The title indicates a reversal of the approach to the matter of curriculum-making which many engineering schools have had under consideration for some time. Some of you have been interested in broadening engineering courses to include business subjects; I am interested in broadening business courses to include engineering subjects. Recognizing the fact that their graduates have frequently been called into positions of general management and into other phases of business operation, these schools have enlarged their curricula to provide business courses to supplement their basic, engineering offerings. What to exclude and what to include has probably proved to be a very nice question. It has been answered, very largely, by offering cost accounting, finance, personnel and marketing courses from the field of business, and superimposing these upon the engineering curriculum.

The Purpose of Business Education

I have always felt that if the question were raised as to the purpose of engineering education, the responses from those connected with engineering schools would be quite uniform. It has seemed, that if they were asked to indicate the desirable curriculum approach to the accomplishment of that purpose, that there would be considerable unanimity in the choice of subject matter. If these assumptions are correct, they are somewhat in contrast with the situation as we find it in business education. In the first place, the purpose is not so definite, and in the second, there is not the same degree of unanimity in the choice of subject matter to accomplish an accepted purpose.

The explanation of this condition is not a particularly difficult one. With two or three exceptions, collegiate business education, in the form of distinct schools of business, is quite new. The school of business is the infant member of the university family of colleges. In some places it is considered *l'enfant terrible*, and other members of the family throw up their hands in holy horror at the coddling and the attention which is given to what is considered an already spoiled child.

As a new field of education, objectives may be expected to be somewhat hazy. The materials upon which to build the curricula are still in the process of being organized; indeed, some of the materials are just being discovered. It is not unlike the early history of education in science, in medicine, in engineering, and the other branches of learning. As materials were collected subjects became more and more finely subdivided, then new combinations of these finer subdivisions were effected. Chemistry becomes bio-chemistry, physical chemistry, mathematical chemistry, thermo-chemistry, electro-chemistry; general medicine grows into many specialties, and we have one man to remove tonsils, another to take out an appendix, another to remove a kidney. Today the question is raised as to whether more should not be required in the form of general medical education lest the specialist needlessly remove tonsils or other parts of our being. And in engineering, is there not considerable advocacy of less subdivision and more emphasis upon common principles? In other words, these older schools are changing their objectives.

The desirability and the form of business education is dependent upon what is established as its purpose. The means of realizing the desired end is determined largely by the availability of materials and equipment, and the ability to make use of them. The stated objectives or purposes vary widely. On the one hand there is some confusion between the purpose of general and business education. This is indicated when the end includes, as it sometimes does, the making of "good citizens". There is also variation in the conception of the breadth and depth to which the curriculum should go. This is evidenced in the following list of stated purposes:

1. To develop high class clerks.
2. To develop a social attitude toward business.
3. To train for professional careers.
4. To educate in the principles of business.
5. To train for general management.

Although these are fairly wide differences, the most generally accepted purposes are to provide technical experts and business executives.

Accomplishment of Purpose

If these are accepted as the basic purposes, the next question to be answered is what the technical expert and the business executive should know. In addition to certain technique, it would seem that they should have a comprehensive grasp of the setting and the operation of business. But what is the setting and what are the operations? If summarized, we should probably agree that business is the development and operation of an organization to produce and distribute, or to aid in the production and distribution of goods and services which people want and for which they will pay. The motive force is profits.

Three factors, then, are basic—production, distribution, and profits—and the techniques developed are such as will aid in these directions. Some of the techniques have been more or less fully developed, as in accounting and statistics. In the field of distribution, various courses in marketing have been offered and the list is being enlarged. Many of the agencies which have developed in economic society to aid in production and distribution have provided subject matter for courses in special fields, as in banking and transportation. An outstanding weakness of school of business attempts to teach modern business is the failure to provide for an understanding of the part played by the machines in what is recognized as a machine age. The problems and the effects of mechanization are subjects of the hour. Many business graduates will go into manufacturing plants; they will sell machine-made goods; they will be connected with companies financing manufacturing enterprises, yet they do not think in terms of machinery.

The Effects of the Machine Age

There is a great deal of discussion these days about the effects of machinery upon the worker and upon the consumer, and the subsequent effects upon modern civilization. Machine production appears to be synonymous with "mass production" and the effects upon the operator and the user of the product are supposed to be devastating. "Robots or Men", "Men and Machines", "Love in the Machine Age", are titles of books, which have appeared within a relatively short time and have discussed this subject. Labor at times resists the installation of machinery and governments attempt to regulate the conditions of machine operation. This year at least one set of college graduates listened to an address upon the destruction of individualism in the machine age. We may ask to what extent individuals were distinct personalities before the advent of the machine? Under the manorial system, in the period

of household industry, in the craft period, how distinct was one individual from another; one household from another; one life from another. In China and India today, in those sections untouched by the effects of machine production and the consumption of machine-made goods, how individualistic are the persons in those communities; how great are individual differences in dress, in thought, in thought processes, in mode of living, in food consumed. We repeat the words "mass production", "mass consumption", and "deadening uniformity", as all inclusive expressions of machine production, as absolutely interrelated, but are they not catchphrases? Look at a colored moving picture of a group of people in a non-industrialized state. Are their head coverings any more individualistic than those of our women in industrial America; do these coverings vary more in shape, size, color, and decorative effects? Look at their footwear, if visible, and compare it with the covering on the quite visible feet of American women. Is there greater variety in design, or in color? Look again at an assembled multitude of women in England, France, or America, and note the gowns which they wear. Is the "deadening uniformity" greater than that of our hoopskirted forebears of colonial times?

The machine age has given us newspapers, magazines, books, radio, moving pictures, quick and low cost transportation. We see distant places and strange people and learn what they are doing. In the colonial towns people thought and talked in terms of what little took place locally; today they talk and think in terms of what is going on nationally and internationally. The difference between talking, acting and living in the broad and individualistic terms of the death of farmer Brown's horse, or the influence of the devil in the life of the community, or the effort of striving to wring enough from the soil in a twelve- or fourteen-hour day to keep body and soul together—the difference between that, and a life lived in terms of a forty-hour working week, or of what is going on in Fascist Italy, or Soviet Russia, the difference between that and thinking in terms of man-made prosperity and depression rather than in terms of a capricious god of feast and famine, is a difference traceable, largely, to the machine. Steinmetz, Edison, Lindbergh, Byrd, the records of the United States Patent Office, are all striking evidences of the deadening effects and the destruction of individualism which is characteristic of the machine age.

Interrelation of Engineering and Business Courses

Schools of business and engineering schools meet on overlapping fields when they get into production. Courses designated as

industrial management, industrial engineering, industrial administration, factory management, production management, are offered sometimes in schools of business, sometimes in engineering schools, and sometimes in both. If offered in the engineering college in a university the business student may take these particular courses in the engineering school (Michigan). If offered in the school of business, the engineering student may take them there (Harvard). What the school of business is not equipped to do, however, is to give that direct knowledge of industrial equipment and its uses, that knowledge of the operation of the machine shop, the forge and the foundry, which the engineering school is able to give. The uses of lathes, drills and machine tools generally; of jigs and fixtures; a knowledge of the types of machines used in plants to heat, mix, compress, bend, twist, and cut the materials processed; an understanding of the conversion of energy and the transfer of power from the point of development to the point of application—these are phases of engineering education which it seems would be desirable for business students to obtain. It seems desirable first, because such courses give a background for an appreciation of what is involved in business management in a machine age; second, because these courses provide practical information upon certain aspects of business management. What it is possible for the engineering school to offer without an extended list of prerequisites in mathematics and science is for you to answer.

Business Functions and their Interrelationship

Knowledge has been broken down into individual subjects and these have been combined into groups of subjects constituting schools or colleges within the university. But these air tight compartments are recognized as defective. It is not sufficient to teach law on the basis of preceding cases; law is being taught in its relation to psychology, business, economics, and changing social concepts. Business is equally complicated. That fact stands out in the study of any business function. The purchasing function may be considered as properly belonging to the engineering school since it involves materials used upon the machines, the testing of purchases, the establishment of standards, and the determination of the uses of substitute goods. But there is a legal aspect to purchasing in the matter of purchasing contracts; there is an economic aspect, since it deals with questions of prices and price trends, demand and supply, the nature of competition; there is a psychological aspect, since it deals with the reactions of the buyer and seller and the consequent technique of bargaining.

An analysis of other functions of business discloses the same interrelationships and the same ramifications. Both law schools and engineering schools could contribute much to the cause of business education. Some of them feel that the business schools have something of value to contribute to them. When there is such a mutual recognition of service, administrative difficulties growing out of costs, stuffs, and similar problems, are simplified. While the contribution of the school or department to another may not be in perfect balance, the result is a better preparation of the student for the field which he is preparing to enter, and that is the end of the education which he is offered.

Discussion

B. M. Brigman: I have not had the pleasure of going over this paper of Professor Filipetti's, but I am interested in some of the comments that he has made. For the past nine or ten months I have been making a study of the schools of business and commerce with the thought in mind that perhaps in the very near future the University of Louisville might enter into that field. I have found, just as the paper presents, that there is a question as to the ends and the purposes to be attained. A mass of data that have been collected from manufacturers, from commercial houses, show that at the present time, in my mind, there is not a very definite purpose established.

Manufacturers tell me that they would desire to have students who are trained in manufacturing and cost work, who would be familiar with shop work, and who can develop into superintendents. On the other hand, you come to the commerce side of the question and they tell me that they are not seeking superintendents, that they want high-type office managers, men whom they can send out into the highways and the byways of commerce. The same thing practically, almost in the same words, comes from the strictly business side of the wholesale or the large retail departments.

The question, as I find it, is one of curricula, one of proper coördination between the engineering phase and the strictly commercial side. That, in brief, is the experience that I have gained at this time. I wish that I would have had the opportunity to go over this remarkable paper. I hope that perhaps later on when these papers are open for discussion that other problems may be presented.

AN EXPERIMENT IN INDUSTRIAL EDUCATION

By GEORGE B. THOMAS

Personnel Director, Bell Telephone Laboratories

For the purpose of this meeting I thought it would be well worth while in dealing with coöperative education to deal with it from the standpoint that anything is coöperative education in which part of the time is spent in industrial work and the other part is spent in educational work, in connection with some definite educational institutional program.

In the Bell Telephone Laboratories we have a definite principle developed through the years, that we will not employ anyone for a job which is a promotion if there is someone in the organization to fill that job, provided the chap in the organization is qualified to undertake the work. The result of this is that the new members of the organization come largely direct from educational institutions. The youngsters for messengers come from the public schools, who because of economic conditions at home have got to go to work at that time. Many have to go to work at the end of high school. Others go through college, and others go through post-graduate work.

We bring in each year in connection with a definite program, numbers of men, and also women, but, relating to this subject, we bring in numbers of young men from all these sources. Every one of these young men has aspirations the same as you and I. Every one of them has parents who hope for them to achieve something more than they were able to with their economic background and educational opportunity. Every one of them wants his place in the sun. We believe that every one of them ought to be given, through some place or other, an opportunity whereby he can qualify to the biggest that is within him for the God-given endowments which he has.

Consequently, having a corollary to this proposition, that if a person is qualified to do the job, if educational opportunity does not exist where they can become qualified, we attempt to coöperate with each and everyone of those groups where it is sufficiently large to justify it, so they can first become better qualified to do the job at hand, and then remove their handicaps in relation to promoting them.

In this program we have developed for the man-power needed for our business an instrument-maker apprentice course, where the young men who are interested in becoming all-around skilled me-

chanics go into the model shop under a definitely prepared program, and have six hours a week work in mathematics, drawing, and the things which they need, to understand better how to read blueprints and how to set the machines, and so forth.

That is not exactly engineering education, but the other functions we have are more along the lines of engineering education. We developed back in the War a training program for high school graduates. Why? Because the supply of people was not available to do the technical things needed, and the men wanted a reasonable opportunity to progress. Engineering graduates were all going into government service. We had to get the jobs turned out with the best equipped personnel we could possibly handle. We tried to experiment by educating young women, college graduates, to do engineering work.

When the War was over and the young men became available, we could not satisfy the young women upon the definite basic aspirations which they hoped to achieve in engineering, with the social background and concepts which we crude human beings have, especially the male factor. The young women felt that since they were doing a technical job they should be able to go forth, climb a ladder, go out and do an installation job, and go here and there. They said they were willing to be sent to San Francisco on a half hour's notice, but social concepts and the rest would not allow it somehow.

Then the next proposition. The young men were selected groups because we had from six to eight applications for every job we got. They were given competitive examinations. We are using the engineering applicant tests, which are the same as those developed by the Iowa placement tests and other tests. We find those young men in an intelligence ratio on the whole are the upper half of those entering engineering classes in colleges.

We also have another principle, that if the young man can definitely go to college in any way whatsoever we advise him to do it. We have talked with many an applicant who came in for a job saying he wanted to get to work because he had economic pressure at home, or because he felt he would learn more rapidly by working and studying at night. We have shown him how it was possible, through scholarships, or working at this, to really put the program forth of going to school.

The reason we do that is because we have found, by the experience of a training program for high school graduates which has been in operation for twelve years, this very simple thing: The salary progress of those high school graduates who were successful in the training program is not as rapid in the grading as the salary program of well-trained, selected groups of college men whom we

employ after graduation. If that is so, and a man can get a program of training which will be most effective for him, we believe we should advise him to take the type of training which in so far as we can tell will give him the broader prospect and the greater opportunity.

We have developed also a training course for drafting assistants, which differs from that of the boys going into the laboratory, because the drafting man goes in more to do designing, and the laboratory assistant goes more into the development aspects through experimentation. That drafting course differs only in this respect: that the content of the class work of six hours a week is different from the content for the fellows who go into the laboratory. In the laboratory they get a little more calculus, a little more analytical theory of electric circuits. In the drafting room they get a little more of the emphasis upon mechanics, upon designs, and upon the strength of materials.

We have arranged also a course where the experts in the business give the benefit of their experience to the neophytes. This we call our After-Hours Training Course. We started that twelve years ago. A few people who are recognized as experts gave classes before and after hours to see whether there was real demand and place for it in our business. We got requests way over and above anything we imagined would happen. There were some 700 requests for these courses. We thought this was a flash in the pan; that after a year or so it would drop by the wayside as other things. It has been continuing for twelve years and it has been increasing year by year. Most of that is due probably to the fact that the organization is growing, and about 60 per cent. of the registration in these classes come from the men who have come into the organization within the past year. Last year we had a thousand people come before business or stay after business to take these courses.

As an outgrowth of these courses we have published tests of the newer departments in the laboratories, books on differential equations, Fletcher's books on the fundamental principles of speech and theory, bringing out through the available educational institutions the actual coördinated information which is brought together through these courses.

We have found they have been highly beneficial within the organization for the purpose of collating, collecting, and coördinating the material which is in the minds of several people. Through these courses they have been put into one source. Some of them may be of service to you people.

We have also a plan for part-time post graduate work at Columbia University. It is at Columbia because we are located in

New York City. The young men who have been on the job for a year or more may apply for this course. If they have done good, consistent work on the job, shown evidence of growth and intellectual curiosity and capacity, they are permitted to go to Columbia for courses which are approved by Columbia and their supervisors. We have had young men who were sort of below average, but they passed. We felt a person doing that kind of work at home was not doing a good job for himself or education; if he was having unsatisfactory family conditions that it might be impossible for him to study, and so on. As a result of this, we have about thirty-five young men who will get their Master's Degree and five of them will get their Doctor's Degree.

We have also an arrangement with the Massachusetts Institute of Technology for coöperative education. This has developed numerous things in our experimental adventures. Five years ago the first group was selected. The young men who wanted the coöperative course were interviewed by the Bell System representatives. They selected a group and this group has gone into the course with five experience programs, alternating fifteen to nineteen months between the time spent at the Laboratory and the Institute. We do not know whether that is really successful or not. We hope it will be. Considering only those who accepted jobs in the Bell System, nobody can tell as yet how highly successful will be the output of the class last year and the class graduated this year. A great majority of the young men have come into employment in one part or another in the Bell System. Some have gone into the New York Telephone Company, some into the Long Lines of the American Telephone & Telegraph Company, some in the Western Electric Company, and some in the Bell Telephone Laboratories.

However, there is this kind of problem. The department which takes a man on part time knows if it gets him after graduation it will have to take time breaking him in anyway. If it gets him as an undergraduate it is perfectly agreeable to take him for fifteen months or nineteen months. Then after graduation if that young man goes to some other department the department which had him all the time feels it was left out without getting and results from the investment of time and influence with the man in his training. You can say since he comes in the Bell System anyhow it is probably an effective things that he got training in one part to be used in another part. It is very hard for a man responsible for output work on the telephone system in the Bell Telephone Laboratories to see it that way.

The students who are put in on full time on the job and are going to any school at night, are also an experiment in coöperative

education. Those young men do not have the freedom of assignment and choice of placement that comes to the young men who are in the coöperative course at the Institute. They are apt to feel, as some of them have expressed, "that the only kind of a bird who gets any opportunity around our business is the fellow who has got money enough to go to college."

We believe our experience and program is such that we can convince those young men that it is not so. Nevertheless, it comes up time after time that you are giving preference to a selected type of group who already has had a better opportunity in life than the other, taking the old Scriptural reference, "To him who has shall be given; to him who has not shall be taken away." The young men feel it deeply. We have got a problem of keeping the men who are on the jobs continuously happy and contented and forward-looking with optimism, the same as we have with the others. It costs a little money but I think the money and consideration is a very minor one.

In the coöperative course in the Bell Telephone Laboratories we have this problem. We have people continuously coming in and saying, "We would like six or fifteen months with the laboratory and we will come without cost whatsoever." The cost is no factor whatsoever from our standpoint. It may be from some other industrial standpoint, but with us it is just a question of whether you can reasonably fit a man into something which needs to be done in such a way that it will not upset the rest of the organization and will actually contribute to the development of a broader plan.

One of our difficulties at the present time is the young men in the coöperative course having too great a field and they do not want to do the actual kind of job they would be doing if they were graduated, or if they were dropping out of school permanently. They feel because they are attending an educational institution that they have got certain rights and freedoms. They are not living directly in accordance with the industrial concepts and requirements. I would say for the young men who have been in this course, however, that every one of them has been of a high-class type and high-intentioned young men. None of them has taken a single advantage of the fact that they are on this type of course. The coördinators, of course, have emphasized the necessity for playing the industrial game even more earnestly and they are more drastic in their criticism of the young men on the course than we are.

The boys tell us they are more drastic in their criticism of their actions than we are. We are in an embarrassing position.

If we criticize the boys very definitely, at the end of the course they may say, "I will go some other place. I don't like that." You see, we have nothing as a result of our investments. We have got that kind of a problem. I found this out through interviewing students who have gone through the coöperative course with other industrial organizations. About 50 per cent of them would come in to see us and say they were angry with the other organization. The majority of those fellows who came to see us would have accepted our position rather than go to the company with which they had their industrial experience. It is an undergraduate point of view that "having had experience with XYZ Industrial Concern, now that I am graduated I will take the job with P Industrial Organization, because that background will be useful in service."

Those are factors that I do not know how to handle effectively, but with the things that have gone so far in my mind we have come to this conclusion. It is an experiment that so far we do not know whether it is going to give a better all-around trained man on the basis of twenty years from now than we will get from the other types of educational programs. There is no doubt whatsoever that the young man who is taking a coöperative course of a year in our industry, and with a coöperative proposition of five years for a Master's Degree at the Massachusetts Institute of Technology, is a better man for the job at the time of graduation than the man who has not had that fifteen months' Bell System industrial experience, because he has had the background with us. On the other hand, I am not sure yet that the man who has had that five years' educational work and fifteen months' industrial experience with the Bell System is twenty years from now going to have a bigger, broader prospective. If we had to decide tomorrow between the proposition of every educational institution sending in the men on the same type of program that they are using at the Massachusetts Institute of Technology, it would be impossible for us to do it, as I see it, and conduct our business.

On the other hand, it may be better through the experience we will get in the next five or ten years. We have faith in it and we are going to continue. We may develop methods which may make it feasible to extend this same principle quite a bit further than it is at the present time extended, but the great value of a coöperative course at M. I. T. as compared with most of the others which I have had contact with, is that they have put into it a definite study program, where a fellow who is on the job also has class work which he has to carry on and which he has to do preparatory to passing.

I believe this will be productive of establishing habits of study and continued studies as a man gets on a permanent job, for as

pointed out in all these educational experiments, in the training course for high school graduates we have developed a group there who are growing up with the habit of study while they work. Many have gone to college. More of them have gone to night school at the Brooklyn Polytechnic Institute, and Cooper Union in New York City. We have twelve who got their degrees this year at the night school. The progress of these fellows is good. I was just studying the people who cross the $4,000 per year salary most quickly. There are a group of ten who passed the $4,000 a year salary together out of a group of close to one hundred who graduated in the same year. These were the first men.

What was the educational experience of those men? One of them from high school went to work in the government departments in Washington. After a number of years working in the government departments he went as an assistant instructor in one of our educational institutes. He then went to another. He got his bachelor's degree at the age of thirty-five. That, however, is a definite progressive channel on the basis of salary.

Three others with similar programs, who had to go out to work anywhere from one to five years between high school or during their college course, two of those fellows were high school boys who went to work with the Bell System immediately on graduation from high school. One was a draftsman, having gone to school at night. He went to Cooper Union and got his electrical engineering degree. At the time he got his electrical engineering degree he was a draftsman in the patent department. He took the Patent Office examination at Washington. He went to Washington and took the law course at the George Washington University at night. He took the bar examination and came back with us last January.

Another one, a young chap, who came directly to us from high school, took our training course for high school graduates. At the same time he went to Cooper Union at night. He got his degree at Cooper Union. Going at night removed his requirements for entering the post-graduate work at Columbia University. He has had several patents issued to him and is one of the young promising supervisors in the organization.

As to the others, two did their college work at night while they were on the job, and four of them came from educational institutions scattered over the United States. One of them was from a coöperative system, not from the Massachusetts Institute of Technology but from the Worcester Polytechnic Institute.

That is specific evidence. In ten years from now we will have a successful, progressive, helpful program or not. I do believe we can tell from the salary progress alone whether they have had

a successful, progressive, helpful program or not. I do believe we can tell if the integrating proposition shows they get in that class more rapidly that it is probably more effective.

We, in the Laboratories, are keenly interested in anything which will attract, develop, and hold the right kind of personnel for us to do a better and a more thorough job. We are interested in co-operative education, and anything we can do to help work it out we shall continue to do. We hope and trust that you people with whom we have had contact so far will give us every assistance you can so that the mistakes we are making and have made shall not be repeated, so that we can build a better course and make something from which we can be sure as time passes that we will get more effective results.

COÖPERATIVE EDUCATION FROM THE INDUSTRIAL VIEWPOINT

By E. B. ROBERTS

Educational Dept., Westinghouse Electric & Manufacturing Company

In his inaugural address as President of the Massachusetts Institute of Technology, Dr. Compton laid down several guiding principles which he felt should become beacon lights in the development of engineering education in America. With two other major points, he emphasized vigorously the necessity for an enlarged mutual understanding between engineering schools and the industries and the development of a spirit of genuine understanding on the part of each of the problems of the other. Every worker in industrial education, and I may say almost all from the industry who are even remotely concerned with the problem recognize the great strides that have been made since 1918 in bringing into harmony the requirements of industry with the objective of the schools. No one, I am sure, would even suggest that the problem is solved or that there is no more to be done. As is usually the case in the solution of all major problems involving the harmonizing of many viewpoints, the first step consists of fact finding and of statements of positions, objectives, and ideals. I suspect that coöperative education has reached that stage in its development.

I understand that the term coöperative education as we use it here is in the narrower sense of defining that particular method of engineering training in which alternate periods are spent on the campus under the guidance of the faculty and in the shop, laboratory, drawing rooms or offices of the industry under the guidance of executives whose primary function is not education but production.

In the industry with which I am associated it has been the policy for very many years, in fact since the earliest days of engineering coöperative education as it was applied by the faculty at the University of Pittsburgh, to coöperate with schools interested in this particular educational method. At the present moment we have in our plants young men from Antioch, Worcester Polytechnic Institute, University of Pittsburgh, University of Cincinnati, Akron University, and the University of Detroit. There are, I believe, some other schools interested in this particular method which have approached us with a view to extending cooperative relationships, but in those cases in which we have failed

to respond it has been because it appeared to us, after a careful study of the individual case, that the expense involved was entirely out of proportion to the result to be obtained.

I have no interest whatever in discussing the wide variety of operating principles as practiced by the coördinators at the several institutions. I assume that all those present who are interested in this problem and are charged with the operating of such programs are familiar with the very complete and interesting reviews and comparisons as they were analyzed by Professor Karl R. Wildes of the Massachusetts Institute of Technology in his paper, "Coöperative Courses and Development and Operating Principles", presented before the Northeastern District Meeting of the A. I. E. E. at Springfield, Massachusetts, last May. The chief differences among the several plans it appears are with respect to the length of the time periods in industry and in school, the frequency of alternation as it were, if we may be permitted to borrow a term from electrical science. These vary from four weeks or less duration to periods extending in one case longer than a year, as practiced by Professor Harold B. Smith at Worcester, with the very selected group of men whom he allows at the end of the junior year to go out into industry and remain there fifteen or sixteen months or until the beginning of college in September of the following year.

From the industrial viewpoint and having had the experience of meeting, assigning to work, and following through their courses quite a number of men from all of these schools, I submit as my opinion that the advantage lies with the long period in industry and infrequent change. Such a plan enables the industry to assign the young man to work on such a basis that some real responsibility can be cast on his shoulders and reasonable standards of performance required of him. In our shops new workers, before they are acceptable as members of the work groups in which they are placed, must be put through a learning or instruction period. In some of the simpler operations, two weeks is sufficient to become familiar enough with the work that what we call 100 per cent participation in the earnings of the group may be enjoyed. In more complicated or difficult work, four weeks or two pay periods are necessary and in yet others six weeks or eight weeks before the worker even though he be a college student is sufficiently accurate or skilled to be regarded as satisfactory. So it becomes apparent that, with the less frequent alternation, there is sufficient time on the specific job to permit the boy to enter into the work that is going on around him in such a way that he can have the feeling when he leaves that particular section that he is leaving something there and that he has contributed to the work of that factory; that he has

earned his way. With all the mechanism that may be set up in industry or school for dealing with coöperative students I am fully convinced that the mental attitude above noted is the real objective toward which this phase of the work must be directed.

Another point I would like to make, and I hope there will be some discussion of this phase of coöperative education, is that its cost seems to the industry to be high in proportion to other methods of gaining the same result. I am aware that there is much to be said on this phase of the problem and there are possibly other views. I am not inclined to believe that any of our schools which have gone in the direction of the coöperative principle have done so as a means of making it possible for young men to earn their way through school. I am inclined to believe that, as a means for so doing, it is distinctly less effective as a program than other methods would be. My point is that any specific industry can, in fairness to its other workers and to the capital that is invested in it, judge one means of accomplishing a result as compared with another means of accomplishing the same result only on a basis of economy and efficiency. Coöperative students in a plant without respect to the service which they may require represent a certain amount of training facility. In our plants we are accustomed to measure this in terms of man-months and it behooves those who are responsible for training to apply these man-months in that direction which represents the most advantageous net return for the industry. In comparing our net results over a period of years from our usual Graduate Student Course with the results from our coöperative programs, as I am sure you suspect, an equal input of man-months does not yield trained men ready for responsible work in anything like the same proportion if applied through the two methods. With our Graduate Course, for instance, slightly less than fifteen man-months on the basis of a year's training program will deliver a young engineer to the regular position in commercial, research, or manufacturing divisions. The coöperative programs require forty-two to fifty man-months to produce an equally well prepared worker.

There is, of course, no thought in my mind that we will ever be able to put one of these plans along side of the other on the basis of an exact numerical comparison in the above terms for the reason that those men who have completed college and entered our industry as Graduate Students represent a group from which the major losses have already been deducted. I submit, however, that one of the major problems which those interested primarily in co-operative engineering training must meet is to devise ways and means whereby a markedly increased number of those young men

on whom industry expends its training facilities later be transferred to that industry well prepared for responsible work.

What I have said about coöperation between educational institutions and industry has had specific reference to the practice and procedure as the plan is used in undergraduate curricula. Before closing my remarks I want to touch upon the plan as it relates to the graduate field. Four years ago, as a result of conferences between administrative officers of the University of Pittsburgh and executives of our Company, ideas on graduate coöperative work advanced by Dean Bishop of the University of Pittsburgh were put on trial. Briefly, the plan was that the University of Pittsburgh would build on its experience and develop the same principles in the graduate field with respect to a very select group of young men from our industry. A plan in complete harmony with the existing coöperative program was worked out, to the end that a carefully selected group of young men engaged in technical work within the industry in the design, development, and research divisions, would be allowed to register as graduate students in the University. The officers of the University visited the plant, went thoroughly into detail in a careful study of the existing training program for the more advanced men, and concluded that it was altogether proper for the University to allow graduate credit for some of the more advanced technical courses found there. Specifically, the courses so approved were those which have grown out of the advanced training developed in earlier days by Mr. Benjamin Garver Lamme, so much of whose effort was put into training young men for the engineering side of industrial work.

As the plan is now in operation, of the twenty-four credits required for a Master's Degree, fourteen may be earned in the industry and these represent nine months of assignment at full time instruction. Ten credits are required under the resident staff of the University, and to this end courses are offered by the Graduate School in mathematics, physics, and economics, and the hours are so arranged that these classes are conducted in the early evening. The thesis required, in addition to the twenty-four credits for the degree, is worked out in the industry under the guidance of the same engineers who are engaged most heavily in the advanced instruction. The final and comprehensive examination is conducted jointly by the University staff and engineers in practice. There are enrolled at this time for the Degree of Master of Science more than two hundred and fifty young men. The number of degrees so far granted has been about a dozen, but with the plan now fully in operation, it is anticipated that, with next year, there will be annually a class of fifteen or twenty men completing the program

Courses under the resident staff of the University last term embraced differential equations, vector analysis, advanced calculus, partial differential equations, functions of a complex variable, mathematical physics, electricity and magnetism, and economics.

This program has been in operation long enough for us to feel that it has advanced further than the trial period, and that increasingly as we secure better men from the colleges this phase of coöperative training will occupy a position of increased importance. In the industry, we are very optimistic, particularly on this phase of coöperative education, and I submit the suggestion that those schools which are especially interested in this method should increasingly turn their attention toward the extension of the co-operative principle to the graduate field. There, it seems, lies an opportunity to bring the plan to its highest degree of usefulness.

Discussion

H. M. Morris: What we have been seeing is an extension into industry of university work and methods, and an extension into the universities of industrial interests and their methods. The two are merging and the university lies no longer within its walls but partly outside of its walls. Nor does the industry lie wholly within its property. As a result, both have problems and both have information to give to the other.

One of the chief difficulties has been to teach loyalty to the men in whom the industry invests its money. The university doesn't have to do that. The man graduates from the university and is free to go wherever he pleases. It has become an idea that educated men have held ever since they have completed their education, that their education once gained was theirs to use for service wheresoever they might be called. That idea has to suffer a partial breakdown in view of the fact that industry invests money in men, sustaining part of the cost of their education. Therein lies one of the things that the university can teach through the industry. These men are getting something valuable and it is not unfair that it should be paid for. I do not see anything wrong in the principle that the young man getting part or much of his training from the industry should pay a tuition for it. That will tend to make him more loyal than he might otherwise be.

President Rees: I had the pleasure last week of visiting Drexel. I gave as high an endorsement to coöperative education as I possibly could, feeling in my heart there is a great deal in it for every institution, and that it is a method of procedure which you are all agreeing is growing with more convincing evidence.

Of course there is the restriction that anyone who is contemplating a coöperative education should study the environment very closely and see that the educational methods fit in with that environment. I know, speaking from the employment point of view, that we are having most excellent results in using the product that you turn over to us. I remember speaking down in Drexel of the experience of one of our smaller companies in the Bell System, the Cincinnati Suburban Company. The general manager tells us that he has no college employment problem at all; that all they do is to take the coöperative boys from the University of Cincinnati and they grow up in the business. So there is one of our companies whose entire demand for college men is met from the coöperative students graduating from the University of Cincinnati.

I know in all the institutions with which we have contact that the relations are very pleasant, very profitable to us and to the students, and I take it that it is a fine-growing method of integrating the student during his time of undergraduate work with the problems of business; that it eases the transition between college and industry.

All I can say to you is keep up the good work and develop this type of education to the highest extent you can within the proper environment with which you find yourselves in the institutions with which you are working. I am very glad to see such a large and enthusiastic meeting of the Division of Coöperative Education. It seems to me working more closely within the Society gives strength to the Society for the Promotion of Engineering Education, and I think that it also gives an integrity to the whole field of engineering education that could not be secured otherwise.

I certainly congratulate you all on the very splendid work you are doing and the growing of the movement, the heightening of the standard, and the very evident improvement in the quality of teaching that you are giving to your students under this particular feature.

A. A. Nims: There were one or two points raised by different speakers upon which I would like to offer very brief comments. Mr. Thomas in his discussion made the statement I believe that it was his opinion that coöperative graduates at the time that they graduated and entered business, were probably more valuable than non-coöperative graduates at the same period, but twenty years later the difference probably had disappeared or might even be in the other direction. I am wondering if that really has a bearing on the subject of coöperative education, that is, an unfavorable bearing. At the end of that time would any difference

be due to the type of education received, or due to the individual differences and advantages and efforts which they have made to progress along their own line?

If that is the case, would not the advantage of coöperative education be manifest in the position gained at the time of graduation? Is that not the time where coöperative education proves its own value? The subsequent progress depends more upon the man's initiative and his temperament than primarily on his education.

Then in connection with Mr. Roberts' paper, he made the point that the longer the period the better. Perhaps a little experience along that line will be interesting. When the coöperative course at the institution with which I am connected was laid out some ten years ago, it seemed at that time that two weeks I believe was a very common period of alternation. A somewhat complicated scheme of alternation, involving both two-week periods and four-week periods was inaugurated at our institution. Most of the students at the beginning were on the two-week period. A few of them were on the four-week period, but the balance gradually changed and last year for the first time the four-week period was adopted to the exclusion of the others.

In connection with Mr. Roberts' statement that the cost of development of the young men to a certain stage by the coöperative method was rather high, am I to understand that that is due to the casualties in connection with the course; that is, originally a large number of men are taken in and those who ultimately come through the course have to bear the whole cost of the expense by the industrial concern upon all from that institution?

A little experience there might be of interest in connection with this institution. We started as a night school primarily, and some ten years ago adopted the college course of four years of coöperative work in the day time. Not so very many years ago, in fact four years ago, we inaugurated a twilight course, which permitted graduates of the night school to complete the requirements for the bachelor of science degree in four years, coming to class between the hours of five-fifteen and seven-fifteen at the same time and for the same calendar year as the college courses.

Recently, we have inaugurated the policy that any man who enters coöperative education (and, by the way, our men do not enter coöperative education until they have completed two years of full time college work. That means only the last two years of the four-year course are on the coöperative basis) by means of this twilight course he can practically duplicate the daytime coöperative work and still hold down a job in industry. Anyone who

qualifies at the end of the sophomore year for cöoperative work and enters upon it, is considered as practically under contract to continue his coöperative course for two years. If, because of academic work he is in difficulty, that is not to interfere with his coöperative work; that is entirely a college proposition, and arrangements for removing that condition are to be made up outside of his coöperative time, usually during the so-called twilight course. In that respect the twilight course has proved to be of great advantage.

Fred E. Ayer: I would like to bring out one point which has not been stressed in connection with this coöperative work. We have referred to the length of the alternating period, and also the recommendation that this be used in connection with the graduate school work. We have a growing unrest in labor circles in this country which is marked by all industrial leaders, and if we do not give our engineering students contact with labor problems, and not as engineering problems, at an early time in the age of our prospective leader in industry, we will not have at hand the solution of these personnel problems which confront all industry today. If we are going to bend all our efforts toward the production of technical engineers, no matter how proficient they are in the profession, but leave out of the picture human problems, we are liable to run into very serious labor difficulties.

We have to bear in mind that there are 46,000,000 wage earners in the United States, and that if they should wield their influence under proper leadership at the polls they could legislate business and industry out of existence entirely, and if we do not instill into our engineering students a proper realization of these problems, a proper sympathy toward the attitude of the average working man, then in my opinion there are three possible difficulties which the country may encounter. We may go so far as to have a Soviet Government, which is probably unlikely. We may have proper leadership developed in labor circles, and this so-called technical employment at the present time is throwing out quite a large number of college graduates. They are becoming as disgruntled as some of the other unemployed men in the country. Out of those ranks we might develop a leadership, a labor leadership, which would be able to weld together the 46,000,000 wage earners, or a large proportion of them, and get them to exercise their influence at the polls.

Not so very long ago, within the last year, a certain insurance company not only inspected the physical equipment of a plant, the safety devices and so forth, but it made very careful inquiries into the group morale of that particular organization before it

would write the insurance. If that is an indication of what may happen in the future, it is not at all inconceivable that the time will come when the financial circles—and we know that something like twelve or fifteen banks in the United States control 70 or 80 per cent of the financial resources of the country—those financial organizations, will be called upon to take care of the capital requirements of industry in business, and they may not only inspect the physical equipment but the group morale of the organization. If that is the case, then we will be at the point where we will have to consider very seriously the whole matter of employment relations, the whole matter of industrial relations between employer and employee. The point I wish to emphasize particularly in connection with coöperative work is that unless our coöperative students have actual experience in the labor end of the work and can appreciate from personal experience the attitude of mind of the ordinary laboring man, they are not going to develop to the fullest extent the advantages of the coöperative system.

Harold Pender: May I say that I am from Missouri, because I am one of those men that Mr. Roberts referred to as not yet being convinced in regard to the coöperative system. Dr. Matheson looked around the room when Mr. Roberts made that remark. He seemed to think there was not any here who was not thoroughly convinced. Here is one. I am open to conviction, particularly in regard to the graduation work carried on with the employees of the company, the graduate work being given by a university. It seems to me there you would have the right type of coöperation. Let the man be employed and then the university will coöperate with him, but not ask the industry, to take on part of the burden that the university should take on and carry the man through to his graduation.

One reason I am still doubtful on this question is that Mr. Thomas and General Rees did not seem to be quite in agreement. Maybe I should not point that out, but it seems to me to be so. Mr. Thomas was very much in doubt as to how this thing was going to work out. General Rees was quite confident that the thing was fine and was suggesting that you all do all you can to develop it.

Another thing, Mr. Roberts suggested that the longer the period in and out the better. I wonder if you have given careful consideration to the idea of four years in and forty years out.

As an example of that, we have a man in our junior class this year who graduated from a first-class law school. He decided that he was not interested particularly in law; that he wanted to go into engineering. He came back and started in as a sophomore in electrical engineering. He is one of the best men we have. He is

a man of broad experience. It makes very little difference where you get that broadening. I think you might also find that a man who has had four years in college with an A.B. is a better man when he comes to the engineering school than a man direct from high school.

I would like to ask Mr. Thomas if he can give me the answer to this little question. Maybe I am asking things I should not ask. You talked about a study made of the men who had reached the $4,000 salary after graduation. You made a comparison. You did not tell us how long it took those men after graduation to reach that $4,000 salary. I think that would be interesting.

Mr. Thomas: Three of them around eight years after high school; one of them nine; two of them about eleven; and the other four went up quite a way.

W. H. Timbie: I want to assure Professor Pender about this pessimistic George Thomas. If George is pessimistic he has a reason to be. The M. I. T. course graduated this year fifteen or sixteen men, and the Bell System did not get one of them. They got the fourteen or fifteen, but one of them they missed. He wants to be 100 per cent. In being pessimistic, the beauty of it is he sees the problems and does solve them. I do not worry at all about this problem that the coöperative student puts up to industry. Of course it puts up the problem of unrest among the other employees. It stirs up their ambition to get an education and the company simply has to play its part, and it always wants to do anything it can. There is no company that does not wish to develop every man it has to the utmost capacity and ability.

Take the Boston Elevated Railway Company. They did not have a single educational thing going on until we started a co-operative system with them. Now they have a thousand men every year taking some kind of educational work. They employ a full-time educational director. They say it is a fine thing. That company won the prize this last year for one of the most outstanding railway companies in the country, especially in regard to safety, largely on account of education. So this matter of bringing in an industrial problem and an educational problem is the finest thing in the world. It is a good thing for the coöperative course.

As to what is going to happen twenty years from now, I do not know. Our oldest graduates are only seven years out of M. I. T. The last study shows the curve is going up just the way it was three years ago, when there was reported a 55 per cent faster increase every year than the regular graduate as reported by the S. P. E. E. The curve is going up a little bit faster at the end

of seven years than it was at the end of four years, so we are not worried about that yet.

Many of my graduates have written in to me confidentially just what money they are getting and just what the job is. With the man seven years out, the curve is still going this way (illustrating) concave upward. It has not started bending over that way yet, and it is 55 per cent steeper still than the curve for the seven-year men as presented by the report of the S. P. E. E. for the engineering graduates of the country. We give those fellows one year out before we begin to talk. Our men are M.S. men so we can not compare them with the straight B.S. men. We are comparing our men with the eight-year men.

The answer to what the men are going to do is first to get better men. Our method of running the course is simply to pick the best men and put them into the coöperative method. There is nothing against the other methods that will work.

In connection with studying on the outside, there is one little question I want to answer about our teachers. Where the industry is right near the institution that is running the coöperative course, the teacher from the institution goes out to the industry, but we have located a course at Pittsfield, at New York, and at Schenectady. There are quite large groups of men there, so we have one of the engineers of the company doing the teaching. However, he does not do just anything he wants to. He gives them the regular course that the boy would be taking at the Institute. He teaches under the direction of the Institute. His work is all laid out for him just as though he were right in the next room. His work is inspected, and the boys take an examination when they get back to the Institute on that course as though it were given in the Institute.

Just think of the material though that the boy gets on the side! Wouldn't you like it when you were taking different parts of electrical engineering to have had an instructor, a fellow, right on the job teaching you at a regular electrical engineering profession, and giving you all the sidelights, that wealth of material that he has gathered, and his experience? He does that in addition to the regular work. He is held right down to the regular text book instruction. The work we give at the Institute does not compare with the work that these engineers do on the same text and in the same daily assignments.

So the instruction after work is one of the finest things in itself. Then, of course, the habit of study. The only complaint I have about that is that it is rather expensive. One employer complained to me that his company had to buy during the second year for *one*

of these men in his employ after he had graduated, over $20 worth of books for the library because this fellow wanted to look up certain things and it took some rather expensive books to do it. He said, "That boy is very curious. He can not get over that habit of studying. It is very hard to get into, but it is just as hard to get over."

Professor Filipetti: I noticed the emphasis made a few minutes ago by Dean Ayer on the labor side of industry and the need of some training in labor. There are several important sides of industry which should have just as much emphasis as the labor side. There is the question of what makes the consumer buy. The fear of the overthrow of the present government and the fear of the development of the Soviet in the United States may be offset, if you are afraid; but determining what factors will increase the purchasing power of the dollar that the laborer gets, the purchasing power of labor, the factors which make for the purchase of goods, the economy in the distribution of goods made, are all factors equally as important as this emphasis upon the industrial relations themselves. So far as Soviet Russia is concerned I do not think we ought to fear that. As an economy, I hope that the Russian Soviet experiments will continue, and as an economy, I hope that the experiment in Italy will succeed. We will then have an opportunity to compare the Soviet régime with the so-called capitalistic régime.

So you have other phases of this thing as well as the labor phase, which are quite as important. It ought to be an important part of this training of engineers to fit them into the business picture.

T-SQUARE PAGE

FREDERIC G. HIGBEE, *Editor*

APTITUDES FOR ENGINEERING: THE POWER TO VISUALIZE

DR. CLAIR V. MANN

Chairman, Committee on Research, Division of Engineering Drawing

Since 1925 Dr. Clair V. Mann has been studying aptitudes for engineering. Among the aptitudes studied is "power to visualize." By psychologists and engineering writers, according to Professor Mann, this has been designated variously as the "faculty," "power," "quality," "capacity," or "special aptitude" to visualize—"see with the mind's eye."

Dr. Mann has collected from one hundred most eminent engineers of the United States opinion as to value of this quality to engineers. Answers have been carefully analyzed and tabulations made. Consensus of opinion is that "power to visualize" is indispensable to the designing engineer who accomplishes more than routine work and that most engineers found capable of designing works of magnitude have seemed to possess this quality in high degree. Most engineers who submitted replies indicate that in design and construction they utilize this ability, conceiving first the work as a whole, then gradually extending "vision" to all details.

Literature of engineering relating to qualifications of engineers and engineering students is certainly full of statements that imagination, power to visualize, power to "see with the mind's eye" structures that do not exist, are qualities which the engineer must possess if he is to succeed.

Diverse opinion exists as to whether this quality is purely "native" (and so incapable of development or training) or whether it can be considerably developed, and should be so developed in the *engineering student*. Opinion relative to types of courses which develop the ability indicate that, of all subjects taught in the engineering college, descriptive geometry, in a peculiar way, tends to develop this quality. Writers of textbooks in descriptive geometry, practically without exception, introduce their subject with the statement that descriptive geometry definitely detects and develops this quality.

Readers should note carefully that the above is a summation of opinion. The real *study* of this quality is being conducted in Professor Mann's laboratory and in classrooms of his department at the Missouri School of Mines. Here tests are being devised which definitely *measure* this quality. The consensus of opinion referred to above seems to indicate that engineers do not know of methods whereby power to visualize may be *definitely, qualitatively* or *quantitively* measured. Measures of both types are being used in this study and intensive research is in progress which will ultimately supply *numbers* of measures of this kind.

THE PLACE OF SOLID GEOMETRY IN THE MATHEMATICS CURRICULUM AND SOME METHODS OF PRESENTING THE SUBJECT *

By LOUIS O'SHAUGHNESSY

Virginia Polytechnic Institute

It was with pleasure that I undertook to prepare a paper with which to open the discussion concerning "the place of solid geometry in the mathematics curriculum and some methods of presenting the subject."

There is a general impression that there is considerable opposition to having mathematics, particularly solid geometry, in all curricula.

So may we not consider first the question: To what extent is mathematical training necessary in general education?

The need of mathematically-minded men in all the walks of life is becoming more and more evident. In politics, in religion, in law and in general business, we encounter only too often, very striking instances in which logically directed reasoning from accurate premises to a sound conclusion is almost completely lacking.

The propaganda method of attaining one's desires has supplanted pure reason, to a very great extent, and has tended to weaken our social, religious, legal and economic structures.

The modern social philosophy that individual responsibility does not exist, is tending to weaken organized society; the many isms of religion are diverting the people from a sound religious philosophy; the devious legal technicalities are affecting the standing of our courts; while, under a peculiar, new economic philosophy we have been living in an economic haze for a decade.

We were told that we were in a new financial era in which the old laws of economics no longer held—we were in an era in which the more we produced the more we could sell at a greater profit, so as to produce still more and sell at a still greater profit. Such a statement seems ridiculous and yet it is not one whit overdrawn. This may be called perpetual motion as applied to business.

However, last October we learned that there is nothing new; that our financial leaders had reasoned only for the immediate present with no eye at all to the future; and, finally, when the break came, their explanations were, if possible, worse than was their original advice.

* Presented at the 38th Annual Meeting, S. P. E. E., Montreal, Canada, June 26–28, 1930.

Time forbids citing almost innumerable instances in support of the above statements.

Furthermore, in the colleges, doubtless most of you have observed the attitude of many arts or finance students who come into a mathematics class. They are inclined to argue about the soundness of mathematical reasoning and conclusions and seem to wonder how an exact science can exist—in fact the conclusions reached are so positive that they are astonished that there is no room for argument. I have had many interesting and instructive instances of the above to come under my observation.

I know that I am speaking to a group favorable to having mathematics in educational curricula, but I wish to say that from direct contacts with modern business I am of the opinion that mathematically trained men are very badly needed; and, that because of this need, mathematics should be included in all educational curricula.

After I had written the above I received a copy of the addresses delivered before the Association of Virginia Colleges, last February. May I quote from a paper by Dean Page, of the University of Virginia, on Mathematics as a subject prescribed for college graduation? "All clear and accurate thinking is done along logical lines. Professor Cassius Jackson Keyser, of Columbia University, a profound Mathematician and Philosopher, says that 'Symbolic Logic is Mathematics, Mathematics is Symbolic Logic, they twain are one. This is one of the greatest discoveries of our age.'

"All logical thinking can be expressed through Symbolic Logic, i.e., Mathematically. Hence, all clear and accurate thinking may be said to be along Mathematical lines, although the thinker is generally unconscious of the fact." "If Professor Keyser is right that Logic and Mathematics are one (and I think he is right) then I see no reason to be surprised at the leading rôle played by Mathematics in modern Physics or in any other subject, if the latter is to be developed logically."

"Now some of my friends in educational psychology tell me that the mastery of one subject does not assist in the study of another, except insofar as the subjects overlap or are 'correlated.' Therefore, since it is true that the accurate thinking of the world is (consciously or unconsciously on the part of the thinker) shaped in mathematical moulds, and since the study of other subjects helps little in preparing these moulds, it would seem that to eliminate or reduce further the study of Mathematics in school and college would strike a sad blow at accurate thinking."

These quotations help to confirm my opinion as to the need of Mathematics in all curricula.

Our second question is: What mathematical subjects should be taught?

I believe it may be assumed that one should be trained in both geometry and algebra, that is, in the two types of reasoning inherent in these two subjects.

Certainly no education in mathematics could omit geometry entirely, and, if geometry is worth teaching at all, why should we confine our study to space of two dimensions—since our entire existence and all of our experiences are in space of three dimensions? Is it not necessary that one should not be a "flat lander," but should be thoroughly acquainted with three-dimensional space and the ways and methods for measuring and determining the relative importance of different bodies in space?

Solid geometry is the first subject to appeal to the powers of visualization and, with its complementary subject descriptive geometry, is most helpful in mental development. Their counterparts in analysis are oral or mental arithmetic and oral or mental algebra.

Geometrical reasoning causes one to hold to the original premises and reason straight forward to a sound conclusion—or at least to a conclusion not at variance with the original hypotheses.

The weakness of many sciences, which are in a process of growth or development, is that the whole groundwork of the science is uncertain and the tendency to make a debating society out of any meeting in which the subject is discussed leads to loose reasoning and to a very changeable kind of philosophy.

Of course, the frontiers of mathematics are not stationary—but the ground work of the science is so well fixed that no other science can take its place in the accuracy of its reasoning.

It is these elements of consistency, certainty, cogency and clearness which make mathematical training so valuable and no subject in mathematics has these elements to a greater extent than has solid geometry.

The importance of solid geometry in the engineering curricula is generally admitted. It is extremely important as a prerequisite for spherical trigonometry, solid analytical geometry and for the applications of the calculus to surfaces and volumes. In teaching mechanics we should be entirely lost if our students were not acquainted with the mathematical concepts and laws involved in the measurement of solids.

In the college with which I happen to be connected we do not require solid geometry for entrance to the college of agriculture or, in general, to the arts college; however, we are working toward a goal and I hope we shall be able very soon to make it a uniform requirement for entrance to the Institute.

When a student from either of the other colleges happens to be in a mathematics class or a mechanics class in the school of engineering we notice his need of solid geometry, spherical trigonometry and solid analytics because his whole field of study has been circumscribed or limited to space of two dimensions and his ability to visualize, to say nothing of his ability to determine the magnitude of objects in three-space, is almost entirely lacking.

So it would seem that if we leave solid geometry out of the curriculum we shall not only deprive the student of its visualizing processes which aid in mental development but shall from the very necessities of the situation confine his entire mathematical viewpoint to space of two dimensions.

I have studied the entrance requirements of some 96 colleges and universities and I find that practically all engineering schools require solid geometry for entrance, while it is not required for entrance by many of the other schools. The results of that study show that of 70 schools with engineering, 57 require solid geometry for entrance and of 26 schools without engineering, only 6 require solid geometry for entrance. Is it not about time that these conditions were remedied?

I have already referred to the necessity of having solid geometry in the mathematics curriculum—for it seems to be the foundation for descriptive geometry, solid analytics, the calculus as applied to solids and for all subjects of mathematics which have anything to do with space of three dimensions.

It may seem clearer to say that there appears to be no logical reason for omitting the subject from the curriculum—and thus creating an unnecessary gap in the regular development of mathematical training.

A study of entrance requirements made by Dr. J. E. Williams, dean of the college at the Virginia Polytechnic Institute, shows that the ideal entrance requirements for engineers are: four units in English, two units in algebra, one and one half units in geometry including solid geometry, one unit in history, one unit in physics, one unit in chemistry, one unit in drawing and four and one half units in other topics. Students with these requirements satisfied passed 91 per cent. of their required quarter credit hours. Those with solid geometry to their credit passed 81 per cent. of their required credit hours while those without credit in solid geometry passed only 60 per cent. of their required credit hours. These results were obtained by studying the records of 214 engineering freshmen. The total credit hours required were 3,852. This study shows rather clearly the value of solid geometry as an entrance requirement to engineering curricula.

The question as to the time the subject should be taught depends upon the general relations or understanding between the high schools and the colleges in their attempt to articulate their courses in mathematics and to make the progress continuous from high school to college.

For engineering students solid geometry should be taught in the high school either in the junior year or the senior year, while for arts colleges, if absolutely necessary, it may be deferred until the freshmen year in college, although even in this case it is much better to have it completed before entering college. Many mathematics teachers are of the opinion that during the last half-year in high school the prospective college students should have a thorough review in algebra and geometry, and nearly all would be glad if solid geometry were completed before the student enters college.

I am almost old-fashioned enough to believe that it is rather difficult to tell an experienced teacher just how to present a subject. However, it seems to me that in teaching solid geometry we should use all available methods: lectures, board work, written exercises, practical problems, original propositions, demonstrations by means of models and general discussions; viewing the subject first from the standpoint of its subdivisions or units and then as a whole. It is surprising how we may "boil down" the entire subject and thus give the student a general view of the work both from the standpoint of its value in mental development and from its value as a practical help in everyday life.

I have just reviewed a text which divides the subject into lines and planes, surfaces and sections of surfaces, areas of surfaces, volumes and polyhedral angles, and spherical polygons. This is a modern text written by a gentleman who specializes in methods of teaching mathematics.

The text I used first, contains the divisions—lines and planes, polyhedrons, and the cylinder, the cone and the sphere. The text which I used some fifteen or twenty years ago had divisions of lines and planes, polyhedrons and cylinders and cones and the sphere; while a more recent text divides the subject into lines and planes, polyhedrons, the cylinder and cone, and the sphere. The four books referred to are fairly representative of the years 1900, 1910, 1920 and 1930, and I believe that any one of them could very well be made the basis for the outline of a course in solid geometry.

I am afraid that there is no easy road to a knowledge of solid geometry—if there were it would lose almost one half of its value. The development of the intellect is very much like the development of the physical man—by using continually the mind so as to exercise it not to anesthetize it, it grows and increases in power.

However, if the ultra-practical view be taken, then it is sufficient to learn mechanically and in the imitative way. I am certain that none of us believes that the latter is real education.

In agreement with the views just stated I quote from the report of the committee on geometry syllabus which had Professors D. E. Smith, H. L. Rietz, and E. R. Hedrick as chairmen of the three sub-divisions.

"1. Geometry is taught because of the pleasure and profit it gives.

"2. Closely connected with the logical element is the training in accurate and precise thought and expression and the mental experience and contact with exact truth.

"3. The study of geometry cultivates space intuition and an appreciation of and control over forms existing in the material world which can be secured by no other topic in the high school curriculum.

"4. The value of the application of geometry to mensuration . . . is well recognized by all teachers.

"5. Solid geometry is valuable because it cultivates the powers of visualizing solid forms from flat drawings without studying descriptive geometry."

I have felt that the idea of motion is useful in geometry—motion of the point generating the curve, the motion of the curve generating the surface and the motion of the surface generating the solid. The above committee agrees with this idea.

So, from the standpoint of practical usefulness, and also from that of educational value, solid geometry deserves a place in our mathematics curriculum—while the methods of presenting it should be: first, as to logical sequence of theorems, then from the standpoint of the unit, and finally, from that of the subject as a whole. I am a thorough believer in the value of the subject and I shall certainly regret deeply the day when it shall be dropped from any more curricula.

NEW MEMBERS

BROWN, ARTHUR S., Instructor in Electrical Engineering, University of Arkansas, Fayetteville, Ark. C. L. Farrar, W. R. Spencer.

COSANDEY, CHARLES J., Instructor in Electrical Engineering and Mathematics, Duluth Junior College, Duluth, Minn. E. F. Peterson, F. L. Bishop.

CUMMINGS, HAROLD N., Professor of Civil Engineering, Newark College of Engineering, Newark, N. J. J. C. Peet, J. A. Brooks.

DOUGLAS, EARL C., Instructor in Engineering, Joliet Junior College, Joliet, Ill. H. H. Jordan, E. P. Hoelscher.

FINCH, JOHN W., Dean, Idaho School of Mines, University of Idaho, Moscow, Ida. Ivan C. Crawford, J. Hugo Johnson.

FISHER, HILBERT A., Associate Professor of Mathematics, North Carolina State College, Raleigh, N. Car. John M. Foster, R. P. Kolb.

GARDNER, ROBERT A., Instructor in Civil Engineering, Bucknell University, Lewisburg, Pa. D. M. Griffith, W. D. Garman.

GILTNER, CARL W., Laboratory Instructor in Mechanical Engineering, Purdue University, Lafayette, Ind. L. V. Ludy, J. D. Hoffman.

GODEKE, HARRY F., Professor of Mechanical Engineering, Texas Technological College, Lubbock, Texas. J. H. Murdough, W. J. Miller.

GRUMMANN, HERBERT R., Instructor in Mathematics, Washington University, St. Louis, Mo. A. S. Langsdorf, E. O. Sweetser.

HOUGEN, OLAF A., Associate Professor of Chemical Engineering, University of Wisconsin, Madison, Wis. O. L. Kowalke, O. P. Watts.

HOY, ELVIN A., Instructor in Mathematics and Engineering Drawing, University of Hawaii, Honolulu, T. H. C. B. Andrews, A. R. Keller.

MILLER, WILLIAM T., Instructor in Mechanical Engineering, Purdue University, Lafayette, Ind. G. W. Munro, J. A. Sauers.

PAUSTIAN, RAYMOND G., Instructor in Civil Engineering, Iowa State College, Ames, Iowa. A. H. Fuller, Frank Kerekes.

ROLOFF, WALTER E., Professor of Economics, Colorado School of Mines, Golden, Colo. R. A. Baxter, J. R. Morgan.

SABBAGH, ELIAS M., Instructor in Electrical Engineering, Purdue University, Lafayette, Ind. C. Francis Harding, D. D. Ewing.

STILL, ALFRED, Professor of Electrical Engineering, Purdue University, Lafayette, Ind. C. Francis Harding, D. D. Ewing.

VAUGHAN, EVAN W., Instructor in Engineering Drawing, Case School of Applied Science, Cleveland, Ohio. W. E. Nudd, C. W. Coppersmith.

WELLMAN, B. LEIGHTON, Instructor in Mechanical Engineering, Worcester Polytechnic Institute, Worcester, Mass. J. H. Whenman, K. G. Merriam.

DISCUSSION: CAN THE ENGINEERING STUDENT BE TAUGHT TO MANAGE MEN?

Professor Smith is to be commended for bringing to the attention of engineers the fact that there is a demand for men of executive as well as technical ability.

Under the leadership of Dean Hitchcock, we have realized this fact at Ohio State University and during the last five years have been giving a course which corresponds very largely to Professor Smith's outline. In addition, however, to the subjects that are brought up in this outline, we find that the teaching of time and motion study offers special opportunity for introducing the human equations. We also find that the course in "The Laws of Engineering Management," which Mr. L. P. Alford introduced in his book, gives still further opportunity to bring human problems to the attention of our students.

With the close tie-up between our shops and our Industrial Engineering courses there is no question but the engineering student can be taught to manage men. We have done this and are very satisfied with the results.

JOHN YOUNGER.

PHOTOGRAPHS OF PROMINENT ENGINEERS

The American Society of Mechanical Engineers have photographs of 49 past-presidents and 72 honorary members which they can supply at a price of 75c a print, 6 11/16 $\times$ 9 1/4 in size, or $75 for the entire set of 121 prints. They suggest that these pictures can be suitably mounted and framed by members of the Student Engineering societies. Possibly the other national engineering societies have lists of their most prominent members whose photographs they can supply in usable size and at reasonable price. It is thought that such photographs of prominent and successful engineers have both an educational and inspirational value to the engineering student.

COLLEGE NOTES

The School of Engineering, **George Washington University,** is now occupying a new Mechanical Laboratory which was erected during the summer months, housing the Mechanical, Materials Testing, Hydraulic, and Concrete Laboratories, in addition to the Drafting Rooms, a Computing Room, and an Instrument Room.

An unusual feature of the new Laboratory is the adoption of open balconies overlooking the main laboratory floor for use as drawing rooms. The indirect lighting system has been used throughout the building.

Dean John R. Lapham is enjoying his sabbatical leave and is following special research work in the field of Sanitary Engineering at Johns Hopkins University. Professor Arthur F. Johnson is officiating as Acting Dean during his absence.

Mr. Max A. Lett, who recently received his M.S. degree in M.E. at Iowa State College has been appointed as Instructor in the Mechanical Engineering Department of the School of Engineering.

The School of Engineering is offering a new course leading to the degree of B.S. in Engineering. The purpose of the Senior Year of this course, which consists entirely of elective subjects, is to allow exceptional students to center their attention upon a group of subjects in which they have special interest. Students desiring Patent Law may satisfy the requirements of this elective year by completing the first year of the regular course in the George Washington Law School.

The **Harvard Engineering School** is offering this year a new course on vibration problems. This subject is growing in importance in the design of high-speed machinery, but it has been neglected in most American engineering schools, although well established in the schools of Europe. The technical literature on mechanical vibration is very extensive in Germany and to a lesser extent in England, but American engineers have been interested in vibration problems only for a little over ten years. Campbell's famous investigation of turbine disc vibration made for the General Electric Company, the work of Akimoff on balancing, and the work of Timoshenko and Soderberg at the Westinghouse Company are all modern developments which have their roots in European literature. Lewis's paper on "Torsional Vibrations in Diesel Engines" appeared only five years ago. The problems are not limited to the design of machines but arise also in the vibrations of high buildings, ships, and aircraft.

This movement on the part of the Harvard Engineering School is intended to acquaint its graduates with an understanding of the physical and mathematical basis of mechanical vibration and with the literature so that they may handle the problems related to the ever increasing size, speed and power now developing in the engineering world.

The instruction of the course is being given by outside lecturers, Messrs. J. Ormondroyd and A. L. Kimball, the general direction of the course being under Professor Arthur E. Norton of the School.

Massachusetts Institute of Technology.—With this school year the Institute starts upon a new and unusual administrative plan. Dr. Samuel W. Stratton, formerly President, becomes Chairman of the Corporation, and Dr. Karl T. Compton, formerly Chairman of the Department of Physics at Princeton University, takes up the office of President of the Institute. Under the leadership of these two men of science the Institute can pursue more effectively than ever its program of graduate and undergraduate instruction in engineering and sciences.

A new dormitory, offering housing facilities for 210 students, was ready for occupancy this fall. This building forms the second unit of the new dormitory quadrangle.

The registration has increased about 200 this year, bringing the total number of students above the 3,200 mark.

Professor Paul Scherrer of the Technische Hochschule, Zurich, Switzerland, is at the Institute this term giving a series of experimental lectures on "Various Phases of Atomic Theory."

Professor J. A. Schouten of the Technische Hoogeschool, Delft, Holland, visiting professor of the Rockefeller Foundation, is lecturing at the Institute this term on "The Geometry of Linear Displacements."

Swarthmore College.—Howard M. Jenkins, Asistant Professor of Electrical Engineering and Industrial Management, returned to Swarthmore this fall after a year's leave, which he spent with the Arthur Andersen Company of Chicago. Dwight K. Alpern, who substituted for Professor Jenkins in 1929–30, has a fellowship at Columbia University and is studying under Dr. Fink. Otherwise our teaching staff remains the same.

A new Lycoming and a six-cylinder Buick motor make distinct additions to the Mechanical Laboratories, while the acquisition of photomicroscopic equipment marks the enthusiastic beginning of our metallography courses.

October 25th was the annual homecoming occasion for Swarthmore alumni engineers, and was celebrated by inspection trips

through the new Clothier Memorial Auditorium and through our shops and laboratories. A dinner meeting was addressed by President Frank Aydelotte and Professor Jenkins.

Swarthmore is looking forward to the annual student meeting of the Philadelphia Section of the American Institute of Electrical Engineers which is to be held here next spring.

SECTIONS AND BRANCHES

Colorado School of Mines Branch.—A Branch of the Society for the Promotion of Engineering Education was organized at the Colorado School of Mines on October 22, 1930, with a membership of eleven. The following officers were elected: President, R. A. Baxter; Vice President, I. A. Palmer; Secretary and Treasurer, G. W. Salzer.

At the first meeting a paper was given by Dr. George W. Salzer on "Descriptive Geometry as Applied to Engineering Education."

The second meeting was held November 12, and a paper was given by Professor I. A. Palmer on "Engineering Education."

It is planned to have four more meetings during the school year.

Kansas-Nebraska Section.—The Kansas University group welcomed the visitors on November 7 at a 6 o'clock dinner at the Presbyterian Church. This afforded an excellent opportunity for introductions and the renewal of acquaintances.

The session at Marvin Hall Auditorium began at 8:00 P.M. with President J. P. Calderwood presiding. There were 80 present. In introducing Chancellor Lindley of Kansas University, President Calderwood called attention to the fact that this was the first occasion on which the executive head of the colleges represented had appeared as a speaker.

Chancellor Lindley welcomed the visitors to Kansas University and evidenced his interest in the work of the engineer and the teacher of engineering subjects.

President Calderwood then introduced Professor E. D. Hay, Kansas University, Chairman of the Program Committee.

Professor F. E. Johnson of Iowa State College, discussed "Development of Personnel Work in Engineering Schools," relating experiences of his own college days that indicated decided lack of interest of faculty members in his future. This in contrast to recently developed systems of supervision and guidance. Professor Johnson outlined the plan in use at Iowa State College and

also read extracts from letters from industrial employers commenting on various personnel systems. These seemed to indicate the need of further development. Professor Johnson expressed the idea that the faculty owes it to students to advise them of the conditions and requirements they will encounter in industrial activities.

Professor R. G. Kloeffler, Kansas State Agricultural College, presented a paper "A Market Analysis of Electrical Engineering Graduates." Data and graphs were shown as lantern slides. Trends during past years and forecasts of developments in various branches of its electrical industry were used in estimating the number of graduates that can be absorbed by that industry during the next five years.

Professor J. P. Colbert, University of Nebraska, spoke on "Organization of Personnel Work, How to Make it Effective." Professor Colbert dealt principally with the problems of supervision and guidance of the student during his first year. The faculty members must all be of service and assist the personnel officer.

Dean O. J. Ferguson responded briefly to a call for discussion. He mentioned the use of tests devised by psychologists which, with recent revisions are helpful in making classifications. Good personnel work must be based largely on personal acquaintance. Avoid making the system too mechanical.

President Calderwood appointed as a nominating committee

Professor F. A. Russell, Kansas University,
Professor L. E. Conrad, Kans. State Agr'l College,
Dean O. J. Ferguson, University of Nebraska.

Speaking on the topic "The New Telescope at Kansas University," Mr. William Pitt of Kansas City, Missouri, gave an interesting description of the method followed in grinding the lens of pyrex glass for this telescope. In the rough this lens was about 27 inches in diameter and 4½ inches thick.

Following Mr. Pitt's talk the program for the day was concluded by an opportunity for those present to visit the observatory and inspect the telescope in which the finished lens is to be mounted. Many of those present looked forward to a future visit to the completed observatory.

Saturday Morning, November 8, 1930

Meeting called to order at 9:20 A.M. in Marvin Hall Auditorium by President Calderwood. Thirty-five were present.

"The S. P. E. E. Summer Session at Yale" was reported on in detail by Professors M. W. Furr and L. E. Conrad, Kansas State

Agricultural College. Both speakers felt that attendance at this summer meeting had been of definite value. The length of time the men were together permitted better acquaintance and afforded ample opportunity and time for real discussion of many problems.

"The S. P. E. E. Summer Session at Pittsburgh." Professor F. A. Smutz, Kansas State Agricultural College, attended this meeting for teachers of Engineering, Drawing and Descriptive Geometry and quoted from the addresses of several of the speakers at the Session. Professor George J. Hood, Kansas University, also reported briefly on the same meeting. Both speakers expressed appreciation of the hospitality and courtesies shown them by Carnegie Institute of Technology.

"The 38th Annual Meeting of S. P. E. E. at Montreal." The reports of this meeting by Professor J. W. Haney, University of Nebraska, and Professor R. M. Kerchner, Kansas State Agricultural College, brought to us a description of some of the events of particular interest. It was evident from the remarks of these speakers that their attendance at the Montreal Meeting had given them a better understanding of the work and objectives of S. P. E. E.

The business session then followed.

Professor F. A. Russell reported for the Nominating Committee submitting the following recommendations:

For President, J. W. Haney, Univ. of Nebraska,
For Secretary, Robt. Warner, Kansas Univ.
For Chairman Program Committee, O. D. Hunt, Kans. State Agr'l College.

The report of the committee was adopted unanimously and these men declared elected for the ensuing year.

The meeting then adjourned for inspection of the Wind Tunnel in process of construction under the West Stadium.

The group re-assembled at 12:15 P.M. at the University Club, the Kansas University engineering faculty again acting as hosts for luncheon.

President Calderwood presided in the short after-dinner program. Responses by Dean O. J. Ferguson and Dean A. R. Seaton expressed the appreciation of the visitors for the hospitality extended by the engineering staff of Kansas University. Dean Seaton also extended an invitation to the Kansas-Nebraska Section to hold the 1931 meeting at Manhattan, Kansas.

Professor F. A. Russell responded for Dean Shaad expressing the pleasure of the Kansas University group that the number in attendance appeared to have broken previous records.

President Calderwood was particularly appreciative of the work of the Program Committee and of those having charge of the local arrangements.

Final adjournment came at 1:30 P.M.

E. E. BRACKETT,
Secretary

Minnesota Chapter.—The first meeting of the Minnesota Chapter of the Society for the Promotion of Engineering Education for the year 1930 was held Thursday, November 20th. Dinner was served at 6:30 P.M. at the Campus Club. Two speakers, Professor W. E. Brooke of the University of Minnesota and Mr. C. N. Stokes of University High School, addressed the Society on different phases of the subject "The Preparation in Mathematics of Freshmen Entering the College of Engineering and Architecture." The fifty members and guests who were present gave evidence of their interest in this timely subject by participating in a lively discussion following the two addresses. Indeed, had it not been for the timely intervention of President Bryant, it is possible the discussion would have extended "So, far, far, into the night."

The Nominating Committee consisting of Professors Brooke, chairman, Cutler and C. A. Mann, presented the following slate of new officers:

President, George C. Priester, Mathematics,
Secretary and Treasurer, Charles F. Shoop, Mechanical,
Chairman Program Committee, Elmer W. Johnson, Electrical.

Upon the motion of Professor Kirchner, the Secretary was instructed to cast a unanimous ballot for these men for the new officers. The meeting then adjourned.

RALPH E. MONTONNA,
Secretary.

NECROLOGY

BROTHER AZARIAS MICHAEL

Brother Azarias Michael was born in Kinkora, Prince Edward Island, on June 22, 1877. He was ordained in 1894 at St. Joseph's Normal Institute, Amawalk, N. Y. He began teaching in old St. Mary's lower East Side, in 1896, and later was transferred to La Salle Academy where he taught until 1901. Brother Azarias also taught in Syracuse and Troy. In 1910 he was sent to De LaSalle Institute, New York City, to take charge of the enginering courses. He studied at Harvard University. He was assigned to Manhattan College where he taught for eighteen years, the last ten of which he was Dean of the School of Engineering. Brother Azarias died suddenly September 17, 1930. He has been a member of this Society since 1928.

BOOK REVIEWS

Foundations for Human Engineering. By CHARLES R. GOW. Edited by F. ALEXANDER MAGOUN. Macmillan Co. New York, 1930.

"Foundations for Human Engineering," by Charles R. Gow, Professor of Humanics at Massachusetts Institute of Technology, is an edited series of lectures covering the scope of the subject of humanics as applied to the engineering graduate. It is an attempt to fit the graduating engineer to cope with some of the problems, personal rather than technical, which he will encounter during his first few years. Unlike most attempts of the kind, this book does not ladle out advice without any attempt at justification. The most interesting and probably the larger portion of the book is taken up in describing actual experiences, and the morals and precepts are left to the reader. The first chapter is by William Emery Nickerson, donor of the course of Humanics at M. I. T. It is like the rest of the book a helpful list of mistakes possible to the graduate. Every engineering graduate can find much to interest and help him by reading this text.

F. L. B., JR.

Elements of Mechanisms. SCHWAMB, MERRILL AND JAMES. John Wiley and Sons. 372 Pages. Fourth Edition.

This book is much larger than the usual text book that covers mechanisms only. It consequently devotes much more space to the

part on belts, gear trams, gears, link work and straight line motions and is more complete on these subjects than most text books. The book limits itself to mechanisms almost entirely and does not give much space to the finding of accelerations, velocities, and forces in machines.

The addition of problems at the end of the chapters should make the book more valuable for class work. It has many illustrative problems and an excellent list of problems at the end. Only minor changes were made in this edition.

E. K.

Heat Engines. By CHAS N. CROSS. 607 pp. Macmillan. 1930. $6.00.

In spite of some minor shortcomings this book measures up to the high standard of excellence of the previous volumes of the Macmillan Engineering Science Series. The chapters on Steam Turbines and Internal Combustion Engines are particularly valuable. Much valuable numerical data is included in the numerous tables in the text. Short historical sketches of the development of the various devices serve to give the student a good perspective, and to appreciate at their proper value the services of the pioneers as well as the more recent workers in the field of Heat Engineering.

The author does not show in any high degree the power of condensing his discussions into small compass. As a result, some parts of the book appear rather diffuse, and some topics are treated rather sketchily in order to keep the size of the book within reasonable limits. In some instances the author has merely asserted laws which are easily susceptible of proof, and in a few cases he has been led into making statements of rather questionable accuracy. It should be added that none of these errors are of serious importance.

On the whole the book will be a very welcome addition to the literature of the subject.

J. A. D.